FINAL REPORT

FOR

CONTRACT NAS8-39569

Space Experiments with Particle Accelerators (SEPAC)

With

NASA/Marshall Space Flight Center
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Prepared by

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INTRODUCTION

SEPAC (Space Experiments with Particle Accelerators) was selected as a payload for Spacelab 1 in 1974. Tatsuzo Obayashi of the Institute of Space and Aeronautical Sciences was the Principal Investigator of SEPAC. Nichols Research Corporation (NRC) and, before W. Taylor moved to NRC, TRW, have supported NASA/MSFC on SEPAC with a series of contracts since that time. The first Co-Investigator was Michael Sellen, who performed laboratory experiments and numerical analyses to refine the operation of the SEPAC electron beam in space. With Sellen's death in 1979, W. Taylor was appointed Co-Investigator, finishing the laboratory experiments and numerical analyses phase of the SEPAC project, and began detailed experiment and operations planning. This continued until the flight of Spacelab 1 in 1983, when he was Payload Operations Control Center Manager for SEPAC. After the flight, a period of data analysis ensued. SEPAC was then selected for flight on ATLAS 1, with James Burch of SwRI as Principal Investigator. W. Taylor was again tapped for Flight Ground Operations Manager, and a period of replanning began. During this period, he was asked by NASA Headquarters to spend two years in the Space Station Freedom Director's Office at NASA Headquarters as Chief Scientist for Space Station Freedom. Stewart Moses of TRW was put in charge of the SEPAC contract at TRW and supported W. Taylor while he was at NASA Headquarters. While Chief Scientist, ATLAS 1 was launched in 1992, and, again, he was in charge of flight operations for SEPAC. After the flight, he moved to the NRC office in Rosslyn, Virginia to become Director of Space Sciences, and a portion of the SEPAC contract was moved to NRC. It is this contract, between NASA/MSFC and NRC, NAS8-39569, that is the subject of this final report.

SCIENTIFIC BACKGROUND

The scientific emphasis of this contract has been on the physics of beam-ionosphere interactions, in particular, what are the plasma wave levels stimulated by the SEPAC electron beam as it is ejected from the EBA (Electron Beam Accelerator) and passes into and through the ionosphere. There were two different phenomena expected. The first was generation of plasma waves by the interaction of the DC component of the beam with the plasma of the ionosphere, by wave particle interactions. The second was the generation of waves at the pulsing frequency of the beam (AC component). This is referred to as using the beam as a virtual antenna, because the beam of electrons is a coherent electrical current, confined to move along the earth's magnetic field. As in a physical antenna, a conductor at a radio or TV station, the beam virtual antenna radiates electromagnetic waves at the frequency of the current variations. These two phenomena were investigated during the period of this contract.

To support the SEPAC team in investigating the virtual antenna investigations, 1000 high schools in the US were recruited to make ground observations of the waves expected to be generated by the SEPAC beam. These observations were done with the support of the INSPIRE (Interactive NASA Space Physics Ionospheric Research Experiment) organization, which is described in detail in Appendix A, and which grew out of the SEPAC observations.

SCIENTIFIC RESULTS

The first investigation performed was to determine the wave levels produced by the DC component of the beam as observed by the SEPAC plasma wave instrumentation. The results of this study were reported at the American Geophysical Union Meeting in San Francisco, in December, 1992. A copy of the presentation is Appendix B.

The first results from the second investigation, that of virtual antennas, were presented in Atami, Japan, at the invitation of and to the International Symposium on Electron Beam Experiment in Space and its Application. The meeting was held on March 26 and 27, 1992. A copy of this presentation is Appendix C.

At the XXIVth General Assembly of URSI (International Radio Science Union), the next report of the virtual antenna investigation was given. The General Assembly was held in Kyoto, Japan from August 25 to September 2, 1993. Appendix D is the presentation.

The final presentation of results from the virtual antenna investigation was made at the American Geophysical Union Meeting in San Francisco, CA held from September 6 to 10, 1993. The major result of the study was setting of an upper limit of the strength of the induced wave observed on the ground from the virtual antenna of the SEPAC pulsed beam on ATLAS 1. The electric field upper bound is 10^{-5} to 10^{-4} Volts/meter•Hertz$^{1/2}$ for frequencies from 50 Hz to 7 kHz. A copy of the presentation is in Appendix E.

In addition to these oral presentations, a scientific paper is in preparation.

INSPIRE

by William W. L. Taylor

ABSTRACT

INSPIRE(Interactive NASA Space Physics Ionospheric Research Experiment) is a non-profit scientific, educational corporation whose objective is to bring the excitement of observing natural and manmade radio waves in the audio region to high school students. Underlying this objective is the conviction that science and technology are the underpinnings of our modern society, and that only with an understanding of science and technology can people make correct decisions in their lives, public, professional, and private. Stimulating students to learn and understand science and technology is key to them fulfilling their potential in the best interests of our society. INSPIRE also is an innovative, unique opportunity for students to actively gather data that might be used in a basic research project, as is being done with INSPIRE data taken during the recent flight of SEPAC on ATLAS 1. INSPIRE began with a test bed project, ACTIVE/HSGS, which involved 100 high schools, with a centerpiece of making observations of transmissions from the Soviet ACTIVE satellite. The second major project was support to SEPAC in which 1,000 schools participated.

The next major project is focused around the annular solar eclipse on May 10, 1994. Participants (students, teachers, etc.) will observe radio waves before, during, and after the eclipse to study the effects of reduced solar UV on the ionosphere and its ability to support propagation of audio frequency radio waves. The fourth project may be to support TSS-1R, tentatively scheduled for Fall 1995.

Helping teachers and students to make regular observations in another important component. This base effort includes annual fall and spring observing campaigns and publication of a biannual periodical, the *INSPIRE Journal*. State or regional Workshops are also planned.

1. Introduction

INSPIRE is a five year old organization whose objective is to bring the excitement of observing natural and manmade radio waves in the audio region to high school students and give them a new appreciation for science and technology. It also is an innovative, unique opportunity for students to actively gather data that might be used in a basic research project, as is being done with INSPIRE data taken during the recent flight of SEPAC (Space Experiments with Particle Accelerators) on ATLAS 1. INSPIRE began with a test bed project, ACTIVE/HSGS, which involved 100 high schools, with a centerpiece of making observations of radio waves transmitted by the Soviet ACTIVE satellite. While the ACTIVE radio wave transmissions were much weaker than expected because of an antenna failure, HSGS was a huge success, measured by the participation and enthusiasm of the teachers and students involved.

INSPIRE then decided to support the SEPAC investigators on ATLAS 1 with radio wave observations made by 1,000 high schools. SEPAC transmitted audio frequency radio waves with a pulsed electron accelerator that might be observed on the ground. INSPIRE/SEPAC was an even bigger success, again, judged by the dedication, excitement and response of the students and teachers, even though SEPAC was only able to transmit once over the United States.

INSPIRE has proven to be a rewarding project for the students and teachers who have participated and it will continue. A series of regularly scheduled, coordinated observations of natural and manmade radio waves is planned, and the next solar/geophysical event chosen to build excitement in participants is the solar eclipse of May 10, 1994. INSPIRE/ECLIPSE-94 will organize coordinated observations before, during, and after the eclipse to study the effects of the decreased solar UV on the ionosphere and thus on the propagation of natural and manmade signals propagating in the Earth-ionosphere waveguide. The next INSPIRE project may be to support the Tethered Satellite System-1R (TSS-1R), tentatively scheduled for Fall 1995.

2. History

2.1 HSGS/ACTIVE

In 1988, the Space Research Institute of Moscow requested that NASA participate in its upcoming ACTIVE (not an acronym) project. ACTIVE was a satellite launched in 1989 with a 10.5 kHz transmitter onboard to study wave particle interactions and the propagation of VLF waves. NASA responded by appointing W. Taylor as the U.S. Coordinator, and authorizing a group of U.S. scientists to make ground observations and theoretical calculations relevant to ACTIVE.

A volunteer organization dubbed HSGS (High School Ground Station) was quickly established by Taylor; W. Pine, a high school physics teacher; and two amateur scientists, M. Mideke and J. Ericson. The objective of HSGS was to recruit high schools to help gather data on 10.5 kHz electromagnetic (radio) waves which might be observed on the ground. A large number of ground receiving sites were needed, both to enhance the probability of receiving the radio waves from ACTIVE, and to determine the propagation paths to the ground.

HSGS was envisioned as a test bed with several objectives. The first was to see whether high school classes could successfully complete a project that included mechanical and electronic construction and a rigorous data-gathering procedure. The second was to see if high school physics teachers could integrate the instructional material into their curriculum. NASA provided moral support and TRW provided financial support to defray the cost of the packages. The packages included an electronic kit and 161 pages of instructional material. The packages were developed and distributed to interested high schools in California, Ohio, Maryland, Virginia, and the District of Columbia.

Many of the schools that received kits successfully operated them, recording the data on cassette tapes for analysis. The transmitting antenna on the ACTIVE satellite failed to deploy properly, however, resulting in a decrease in signal strength of about 30 dB. Even though no waves were observed on the ground, the teachers reported a very high level of enthusiasm in their students. The teachers integrated the HSGS instructional material into their units on waves, electronics, radio, and the atmosphere. The student and teacher enthusiasm proved to HSGS that continuing such a program would be very useful in stimulating interest in science in general and space physics in particular among high school students. This volunteer organization evolved into INSPIRE.

2.2 INSPIRE/SEPAC

Following ACTIVE and the proof of the concept through HSGS, INSPIRE was formally organized and incorporated by W. Taylor, W. Pine, M. Mideke, and J. Ericson. The objective of INSPIRE was to incrementally increase high school participation by a factor of ten and to more or less permanently establish a set of high school physics classes (through teacher participation) around the country to make observations of radio waves in the audio region. SEPAC (Space Experiments using Particle Accelerators), a payload on the ATLAS 1 Spacelab mission, flown in March/April 1992, provides the initial enthusiasm for INSPIRE classes. SEPAC consisted of an electron accelerator and support instrumentation and performed many experiments in the ionosphere, including producing an artificial aurora and investigating the electromagnetic waves produced by a pulsed electron beam (a virtual antenna).

W. Taylor is a SEPAC Co-Investigator and is the leader of the virtual antenna experiments on SEPAC. The ATLAS 1 payload did not include a subsatellite to receive the waves from the SEPAC virtual antenna, so the logical alternative was to establish a set of ground receiving stations to receive the radio waves. INSPIRE provided that service to the SEPAC investigator team, and at the same time, allowed high school students the opportunity to take data that would be used in a published basic research project.

To publicize INSPIRE, the project sent invitation letters to "The Physics Teacher" at the 10,000 largest high schools in the U.S. (of about 20,000 total). In addition, articles publicizing INSPIRE were published in various journals [*Anonymous*, 1991a, b, c, d; *Ericson*, 1991a, b; *Mideke*, 1991; *Pine and Taylor*, 1991; *Reneau*, 1991; *Anonymous*, 1992a, b, c; *Taylor et. al*, 1992; and *White*, 1992]. More than 1,000 schools (10% of those solicited) responded with orders for the package. The package included an electronic kit, 250 pages of background and instructional material, an audio tape of expected phenomena and a promise to analyze any tapes that were sent to INSPIRE after the mission. Only the first 1,000 orders could be filled due to the limited resources available to INSPIRE. Figure 1 shows the geographical distribution of the participating classes.

An elaborate information distribution network was established to inform the participants of the experiment schedule, including hourly announcements on WWV (the U.S. time and frequency shortwave radio station), announcements as needed on four electronic bulletin boards, and a toll-free telephone number with a recorded announcement that was changed as new information became available. W. Pine participated in mission simulations and the mission, to act as the INSPIRE focus during the mission at the Payload Operations Control Center. ATLAS 1 flew for about a week and the plan called for ten virtual antenna experiments over the U.S.

The electron accelerator failed on its second virtual antenna operation, but many of the high schools participated in the backup listening schedule to study the changes in sferic (lightning impulse) propagation at sunrise. Approximately 300 cassette tapes were sent to INSPIRE for analysis. Each of the participant classes who sent tapes received in return at least one spectrogram of the data they had collected, a personal letter from M. Mideke, who performed all the analysis, describing what they had observed, and a Certificate of Appreciation for participating. As with ACTIVE, the teachers and students were wildly enthusiastic about INSPIRE. The project gave them a means of relating the physics they learned in class to a real, practical experiment, and one that was being done cooperatively with NASA, using the Space Shuttle. Some classes also performed computer analysis of the signals they received.

The observations of one of the INSPIRE participants, D. Griffin, from Ridgefield, Connecticut, are being carefully analyzed by W. Taylor. The data show evidence that waves from the SEPAC virtual antenna were observed on the ground (see Figure 2). Other INSPIRE/SEPAC data will also be examined. The results were reported at the Kyoto URSI meeting in August 1993 [*Taylor, et al.*, 1993a] and will be presented at the Fall American Geophysical Union (AGU) meeting [*Taylor*, 1993b]. A publication is also in preparation [*Taylor*, 1993c].

After the success of INSPIRE/SEPAC, the officers decided to continue the INSPIRE project. Several activities have been identified. One is the *INSPIRE Journal*, W. Pine, Editor, published biannually, which, for a small subscription fee, describes INSPIRE activities and INSPIRE results. Another is a continuing coordinated observation campaign, in which participants across the U.S. make simultaneous observations to study the propagation of radio signals in the audio range. Examples are manmade signals such as the OMEGA and ALPHA radio navigation stations, and natural radio emissions such as sferics (the broadband electromagnetic impulses from lightning) and whistlers (frequency dispersed impulses from lightning).

INSPIRE has organized and participated in two workshops. One was held at Chaffey High School in Ontario, California in December 1990, to acquaint high school teachers and students with ACTIVE and HSGS. Fifty-four students and teachers from 17 high schools attended. W. Pine organized and ran the Workshop. While designed for schools in southern California, one teacher attended from Washington, D.C.!

The second Workshop, this time for INSPIRE/SEPAC, was held at the Academy for Science and Foreign Languages, a public magnet middle school in Huntsville, Alabama, in March 1992. Aimed at middle and high schools in Madison County, 40 teachers and others from northern Alabama attended. It was sponsored by the University of Alabama at Huntsville. W. Pine attended and spoke at the Workshop.

3. Plans for the Future

3.1 INSPIRE/Continuing

Through this proposal, the INSPIRE project will continue, rallying around opportunities for observations of special events, but with a base of activity to make U.S.-wide observations of natural and manmade phenomena. The *INSPIRE Journal* will be an important part of these activities. Plans are for it to be issued in November and April of each year with INSPIRE news, activities and results. In addition, more high school physics classes will be recruited to participate in INSPIRE, to learn about space and NASA through the study of the ionosphere, lightning, electronics, mechanical and electrical construction techniques, data gathering procedures, and data analysis. Spring and fall observing campaigns will be organized to observe natural and manmade phenomena. A schedule for INSPIRE for the next four years is given in Table 1.

Item	1993	1994	1995	1996	1997
Fall Observing Campaign		10/15-31			
Issue *INSPIRE Journal*, Vol 2, No 1		11/1			
Workshops		3/1-5/1			
Spring Observing Campaign		4/1-15			
Issue *INSPIRE Journal*, Vol 2, No 2		4/15			
Eclipse		5/10			
Fall Campaign			10/15-31		
Issue *INSPIRE Journal*, Vol 3, No 1			11/1		
Workshops			11/1-3/1		
Spring Campaign			4/1-15		
Issue *INSPIRE Journal*, Vol 3, No 2			4/15		
Fall Campaign				10/15-31	
Issue INSPIRE Journal, Vol 4, No 1				11/1	
Workshops				11/1-3/1	
TSS-1R				11/15	
Spring Campaign				4/1-15	
Issue *INSPIRE Journal*, Vol 4, No 2				4/15	
Fall Campaign					10/15-31
Issue *INSPIRE Journal* , Vol 5, No 1					11/1
Receive evaluations from teachers					1/1
Spring Campaign					4/1-15
Issue *INSPIRE Journal*, Vol 5, No 2					4/15

Table 1. Four Year INSPIRE Schedule

INSPIRE is dedicated to providing opportunities to all interested students, and giving specific encouragement to those who are generally less interested in or less able to participate in scientific or technical fields. Special efforts will be made to encourage participation by disadvantaged schools as well. Several examples of this encouragement are:

(1) Jill Marshall, the San Antonio Coordinator, has and will make a special effort to involve young women's groups in Texas.
(2) The Society of Hispanic Engineers and the National Society of Minority Engineers has and will be encouraged to sponsor INSPIRE schools.
(3) W. Taylor will attend the NSF sponsored National Conference on Diversity in the Scientific and Technological Workforce to be held in Washington, D.C. on October 28-30, 1993, to promote wide participation. He has arranged to have a special meeting room available to recruit participants.
(4) Local Workshop organizers will be encouraged to have diversified role models participate in the Workshops, including, perhaps, the representative from the local power company, and
(5) Organizers make a special effort to contact and encourage participation by local organizations, such as the Eastern Branch of the Boys and Girls Clubs of Washington, D.C.

INSPIRE plans to hold Workshops each year. The Workshops will be primarily organized by local teachers and volunteers and will be designed to offer an introduction to INSPIRE, its projects, kit building (sometimes the students and teachers do not have the expertise to build the kits without help), site location and data gathering procedures. A Workshop will usually be held on a Saturday, with INSPIRE participants (teachers and students) attending.

A typical Workshop agenda might include short talks by a national INSPIRE organizer, introducing INSPIRE, describing previous projects and describing the next projects (such as Eclipse–94); a talk by the local organizer; a talk about building kits; and a talk by a representative of the local power company. After the formal presentations, the Workshop would typically break up into small groups to discuss particular aspects of INSPIRE, to locate electromagnetically quiet sites, to build kits, to learn more about the phenomena that can be observed with INSPIRE receivers, and to learn about data analysis. A national INSPIRE representative will attend each Workshop as a resource person and to lend continuity to the Workshop.

3.2 INSPIRE/ECLIPSE–94

On May 10, 1994, an annular eclipse will sweep across most of the U.S., with a maximum coverage of the sun of about 88 percent. Since the Earth's ionosphere is primarily created by solar UV, and since radio waves in the audio frequency region propagate in the Earth–ionosphere waveguide, it is natural to assume that the eclipse will have an effect on radio propagation and that the changes may be observable with INSPIRE or ACTIVE receivers. Therefore, the INSPIRE project has decided to make INSPIRE/ECLIPSE–94 its next major observational objective. High school classes, through their teachers, will be solicited to make observations before, during and after the eclipse. Table 2 shows the schedule for INSPIRE/ECLIPSE-94.

Item	1993	1994
Draft of *INSPIRE Journal* articles to Pine	10/1	
Issue *INSPIRE Journal* Vol 2, No 1 with announcement/offer	11/1	
Orders due for receivers		1/1
Solicitation of Workshops		1/1-3/1
Receivers shipped		2/1
INSPIRE/Eclipse–94 Workshops		3/1-5/1
All material in hands of participants		4/1
Issue *INSPIRE Journal* Vol 2, No 2 with evaluation form		4/15
Eclipse		5/10
Tapes due to INSPIRE with completed evaluation forms		6/1
Processed data returned to participants		8/1
Issue *INSPIRE Journal* Vol 3, No 1 with results		11/1

Table 2. INSPIRE/Eclipse–94 Schedule.

Kits and completed electric field receivers will be offered for sale for about $60 (cost) to students, classes, teachers, amateur scientists and others to allow them to participate. Those with HSGS (magnetic field) or INSPIRE/SEPAC (electric field) receivers will be able to use them, of course. Publicity for radio wave observations during the eclipse has already begun with Mideke [1993a; 1993b] and Taylor [1993d; 1993e], and will continue. Figure 3 shows the path of the eclipse in North America [Espenak and Anderson, 1993]. Everywhere in the contiguous 48 states will experience at least a 48 percent coverage of the solar disk as measured by the overlap of lunar and solar diameters.

3.3 INSPIRE/TSS-1R

NASA has tentatively approved the reflight of the Tethered Satellite System (TSS)-1R for the Fall of 1995. The TSS-1 payload includes an electron accelerator which, under some circumstances, will modulate the current in the tether wire. If modulated at audio frequencies, the 20 km-long tether would act as an antenna and might be a radio wave source in the ionosphere that would be detected on the ground. INSPIRE will approach TSS-1 Principal Investigators and the Project Scientist to volunteer INSPIRE observers' support. Two factors will maximize INSPIRE usefulness, an orbital inclination high enough that the orbit covers the 48 contiguous states, and appropriate operations over the U.S.

3.4 Success Evaluation

Evaluating INSPIRE activities is a high priority. We have solicited comments from the HSGS participants and the INSPIRE/SEPAC participants, evaluated the comments and used the relevant ideas in subsequent projects. INSPIRE/ECLIPSE–94 will be no exception, with an evaluation questionnaire already planned to be included with the educational materials sent to all of the schools who participate. The teachers will be asked to return the questionnaire promptly after the eclipse. The results of the returned questionnaires will be tabulated and reported in the *INSPIRE Jounal*. Vol. 5, No. 1 of the *INSPIRE Journal* will include an evaluation section, and recipients will be requested to complete and return it within two months. The results of the evaluation survey will be used to improve future INSPIRE activities and reported in the *INSPIRE Journal*.

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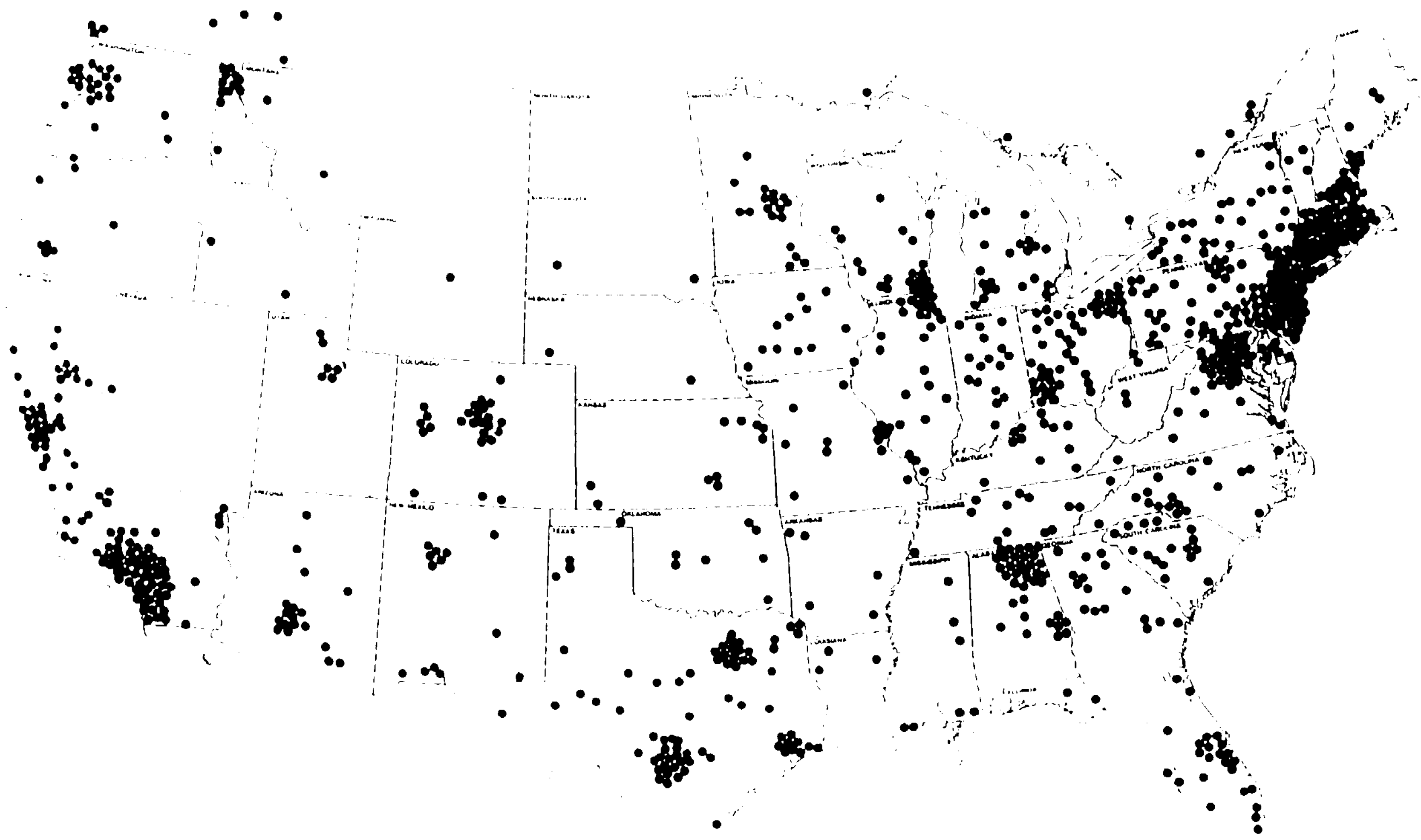
Figure Captions

Figure 1. Locations of the 1000 high schools that participated in INSPIRE/SEPAC.

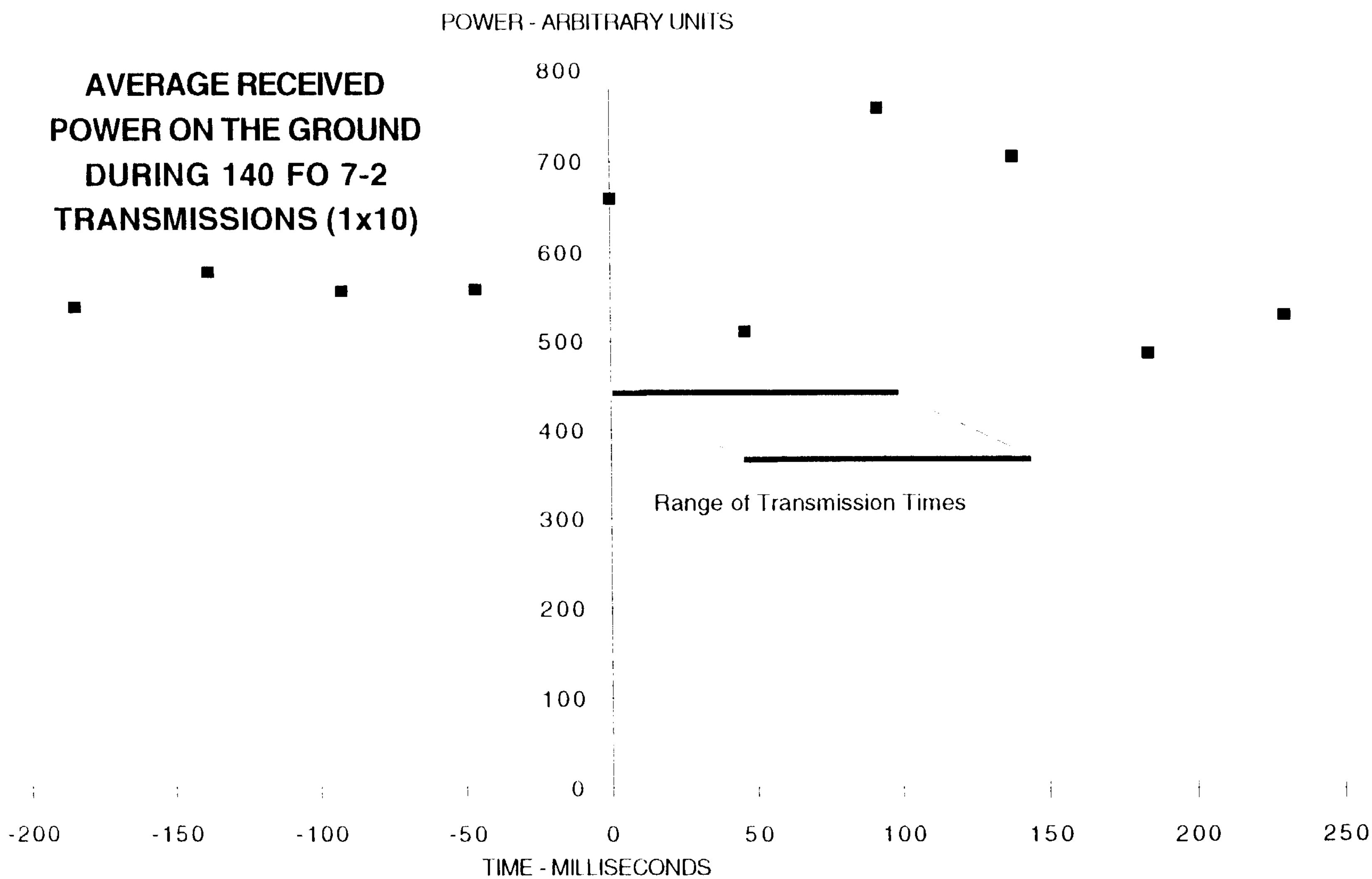
Figure 2. The average power received on the ground during the 140 transmissions during Functional Objective (experiment) 7-2.

Figure 3. The path of the annular solar eclipse over North America on May 10, 1994. The percentages/maximum on the Figure are the overlap of lunar and solar diameters. From Espanak and Anderson [1993].

1000 OBSERVING SITES FOR INSPIRE



AVERAGE RECEIVED POWER ON THE GROUND DURING 140 FO 7-2 TRANSMISSIONS (1x10)



SEPAC on ATLAS 1: Waves Induced by Beam/Ionosphere Interaction Experiments

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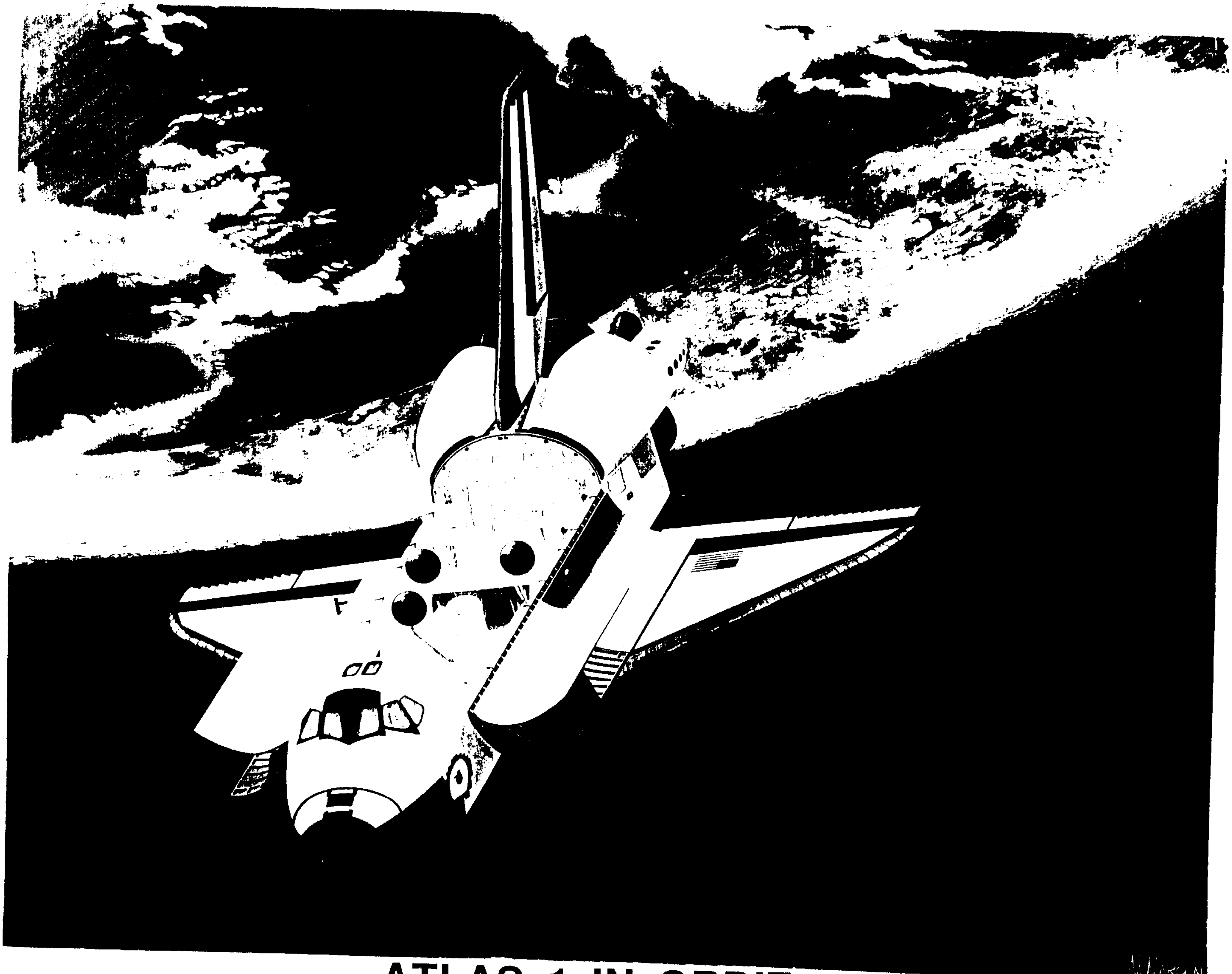
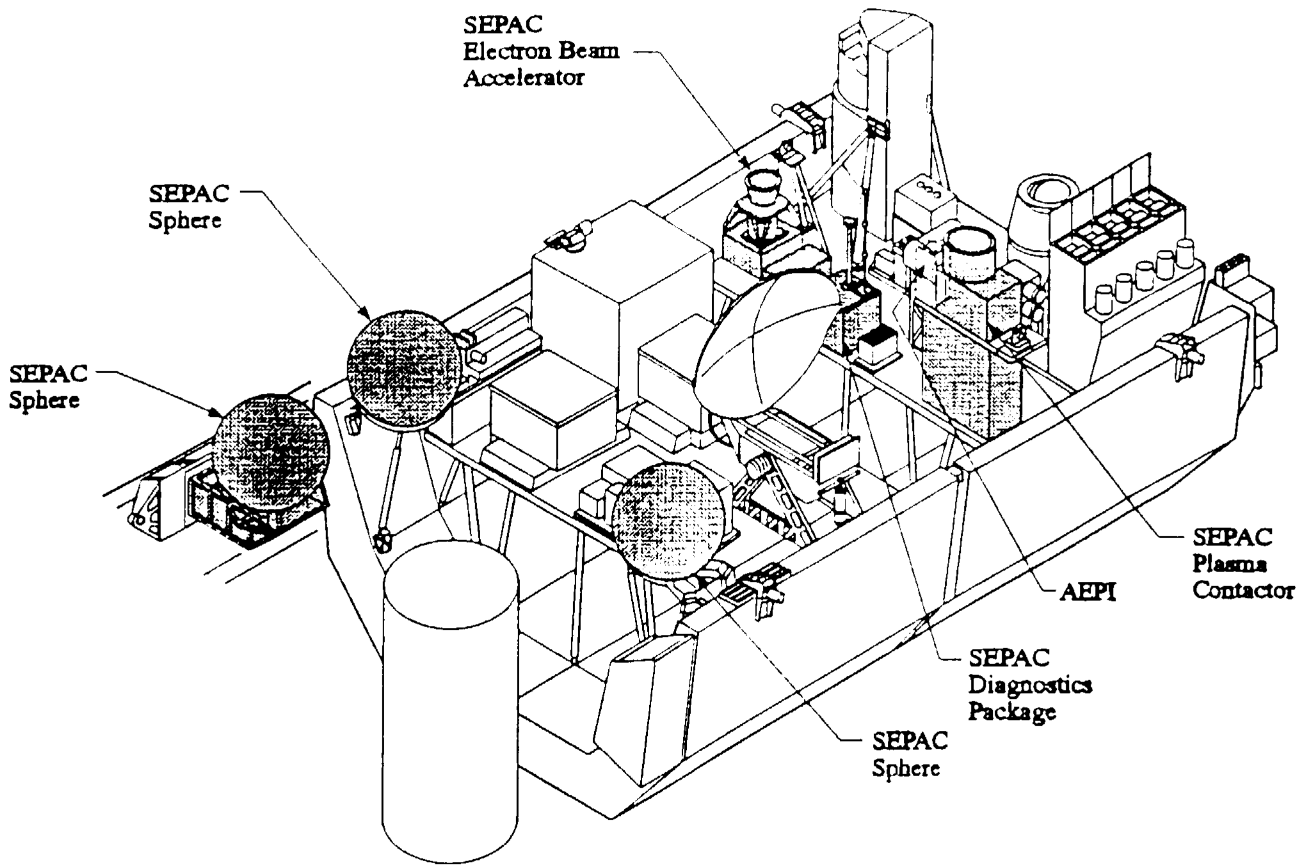
December 7, 1992

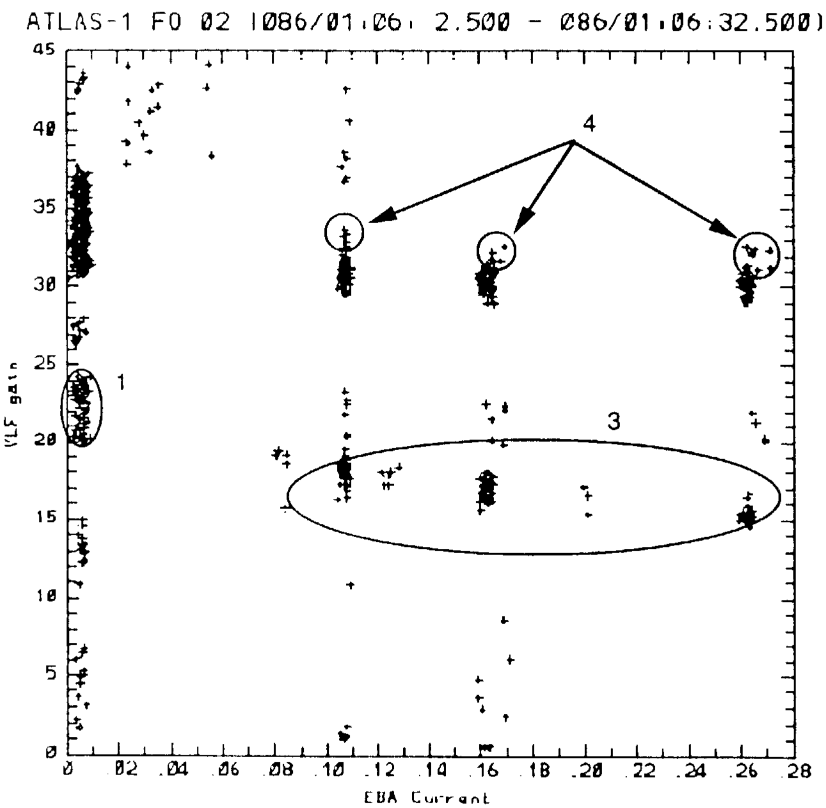
American Geophysical Union Meeting
San Francisco, CA



ATLAS 1 IN ORBIT

SEPAC ON ATLAS 1

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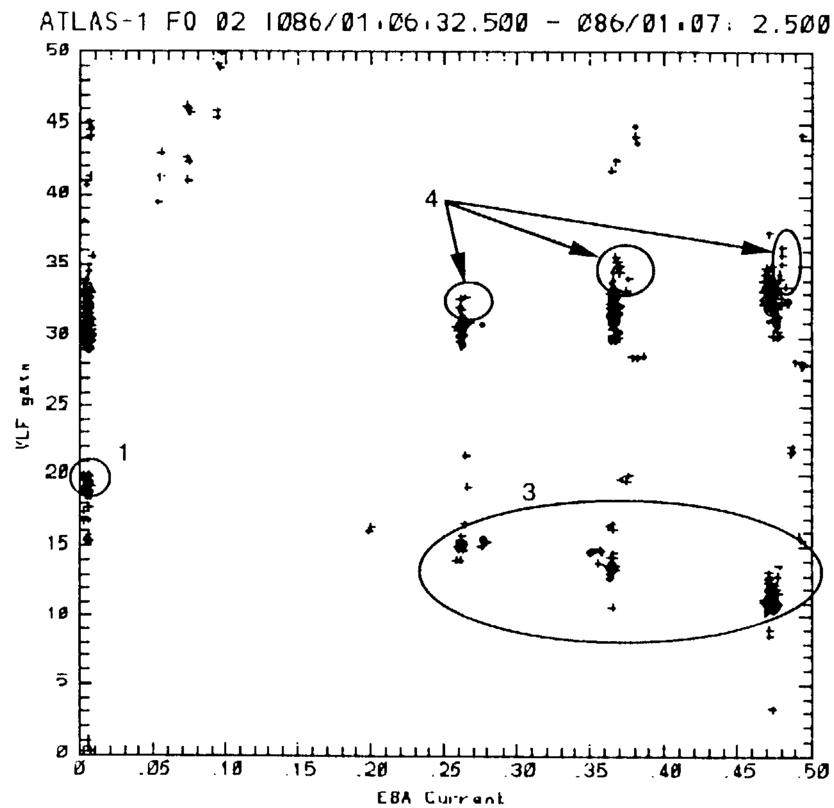
VLF gain
EBA Current
1
3
4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VLF gain
EBA Current
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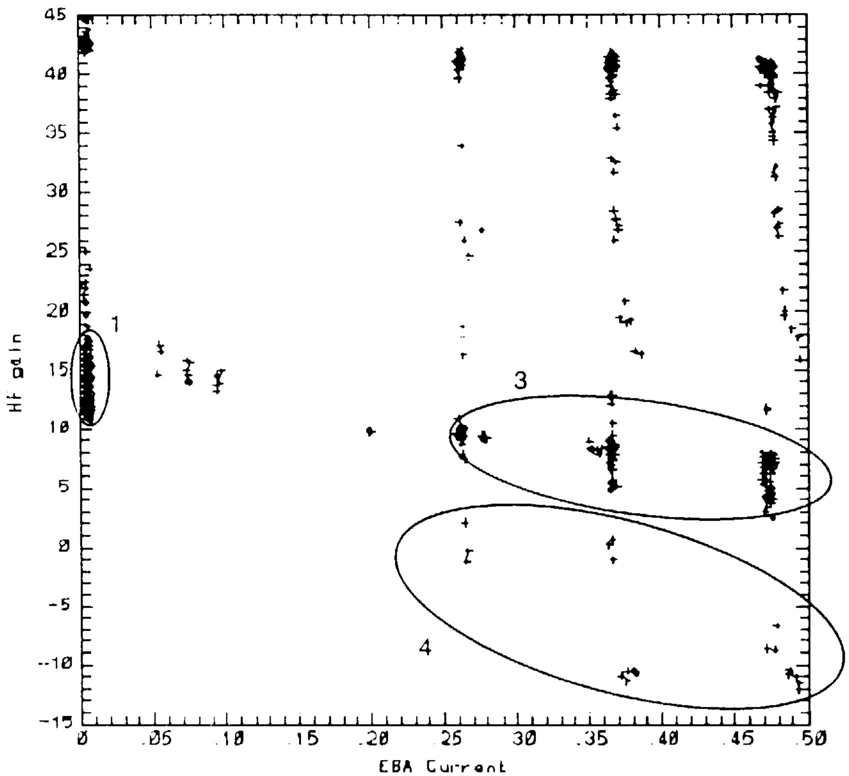

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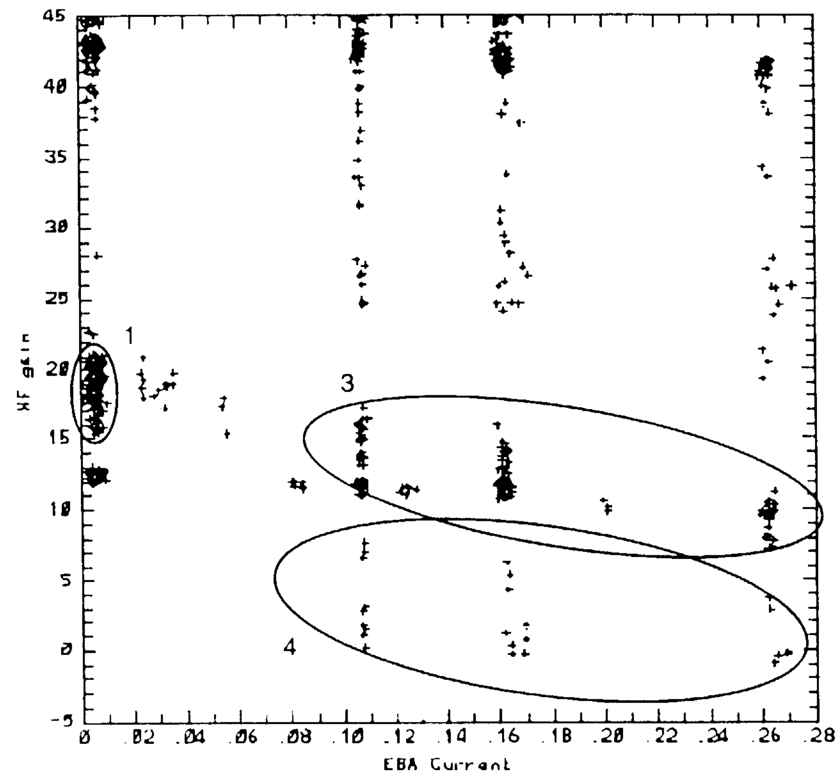

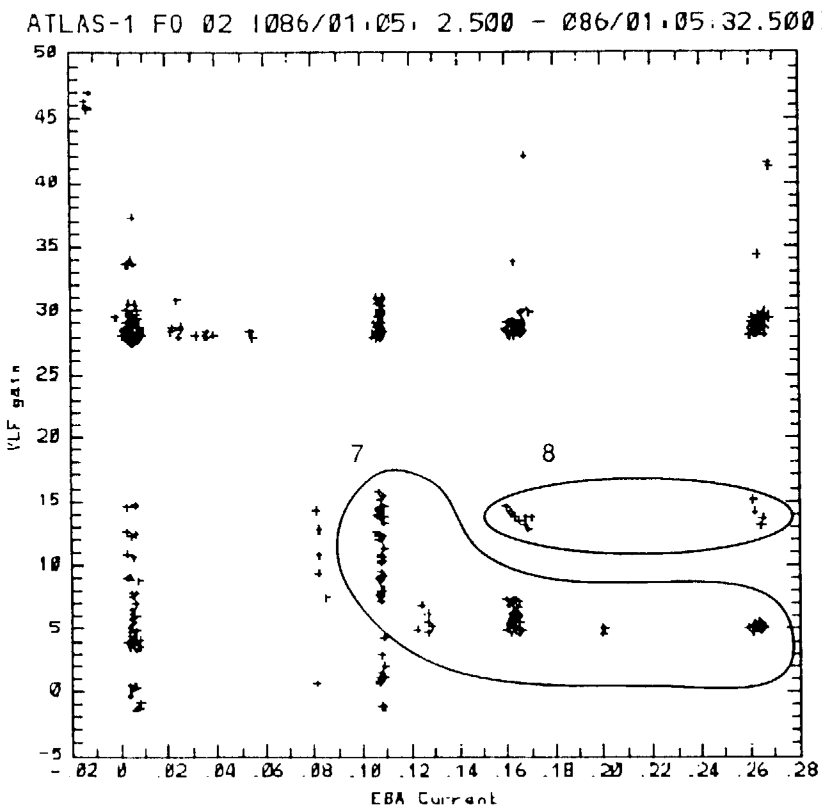
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VLF gain
EBA Current
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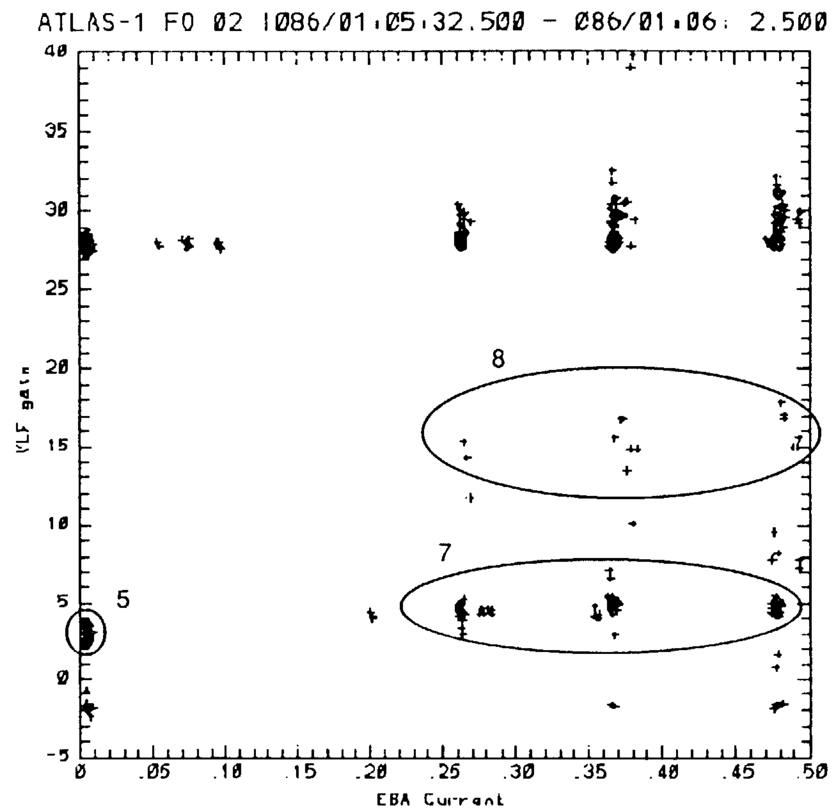
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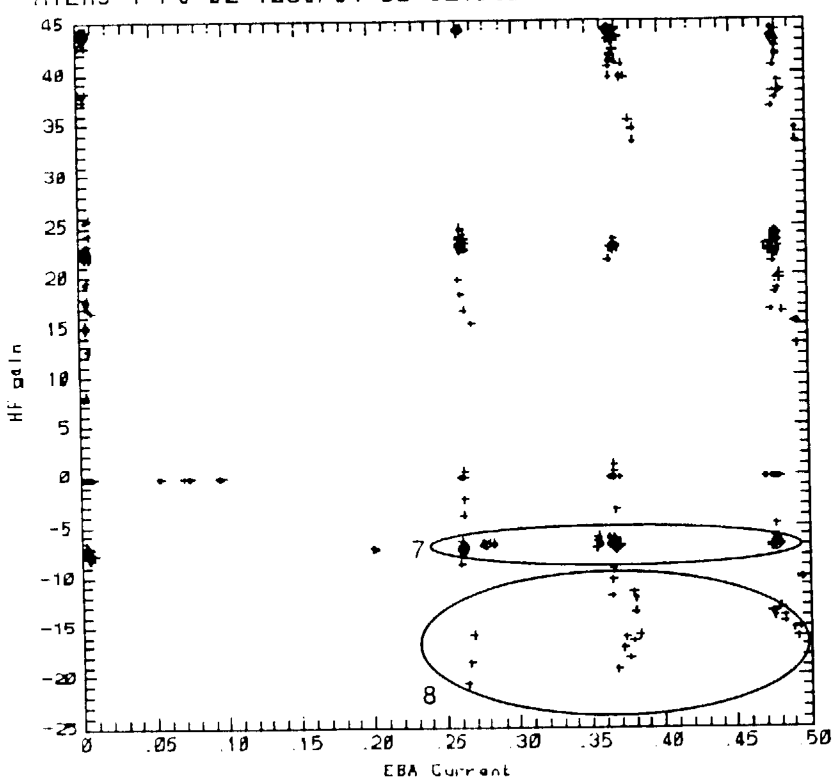
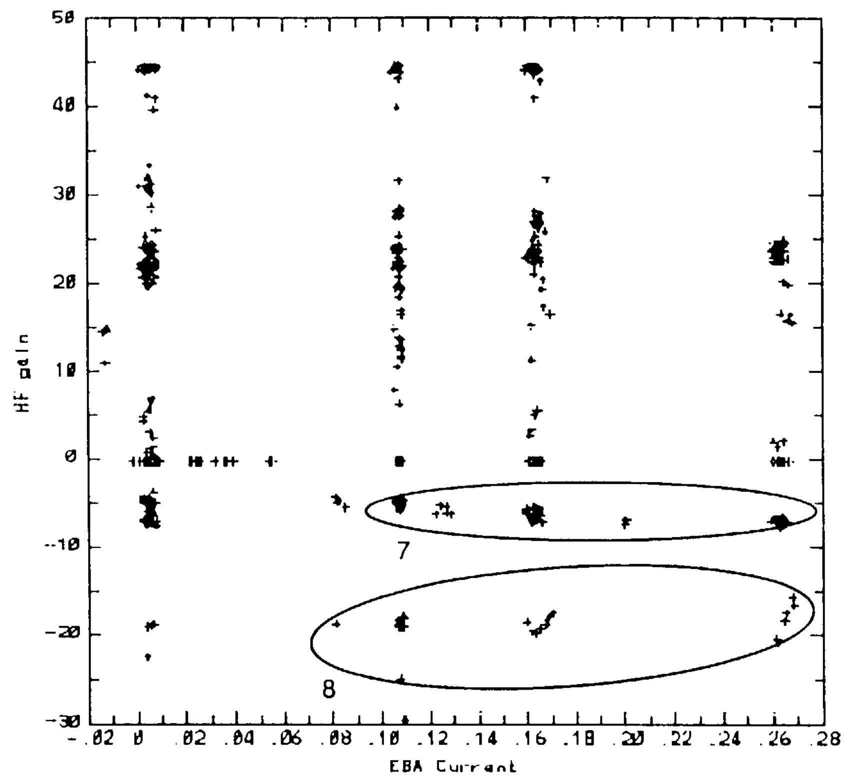
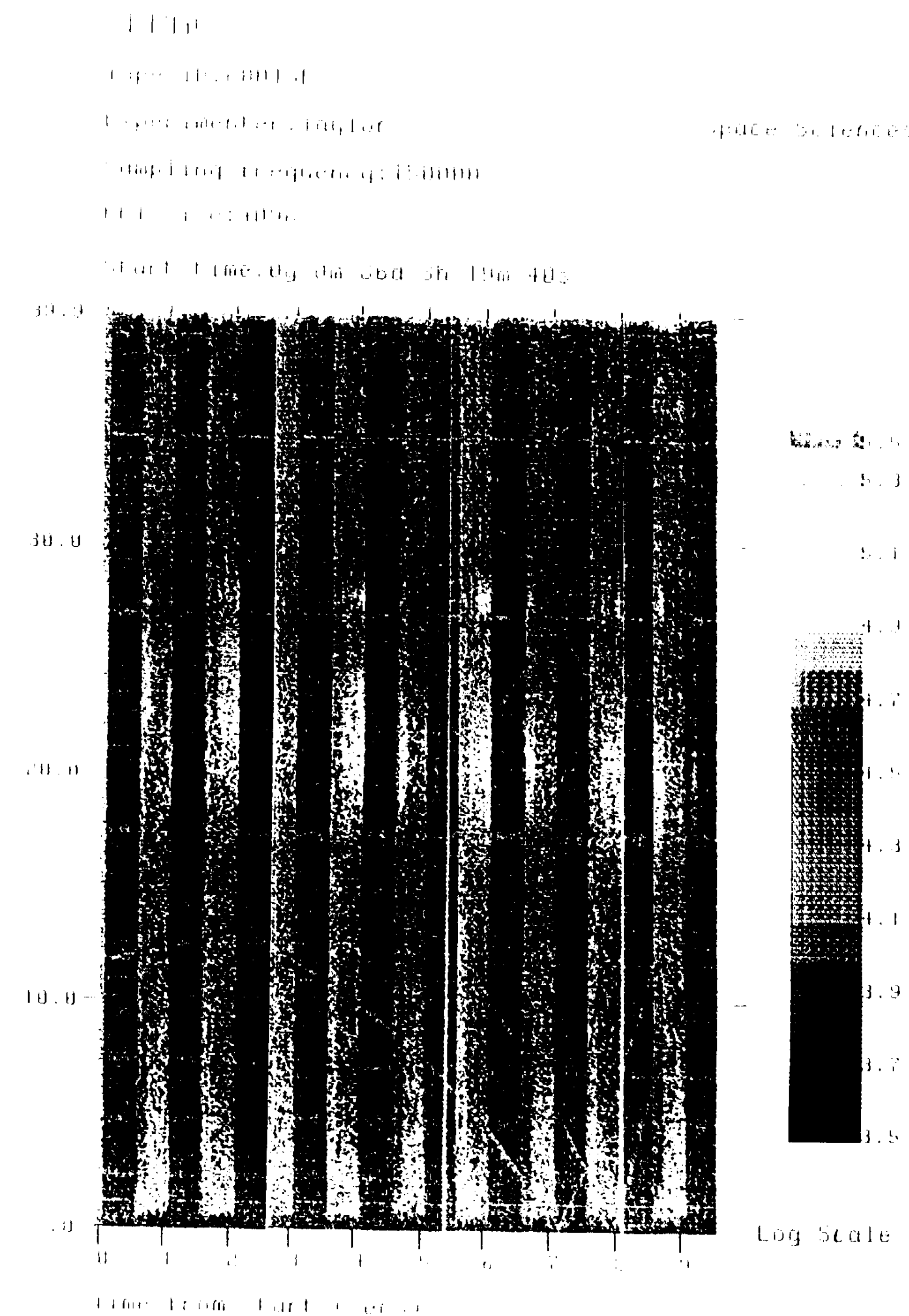
ATLAS-1 FO Ø2 IØ86/Ø1:Ø5:32.5ØØ - Ø86/Ø1:Ø6: 2.5ØØ)

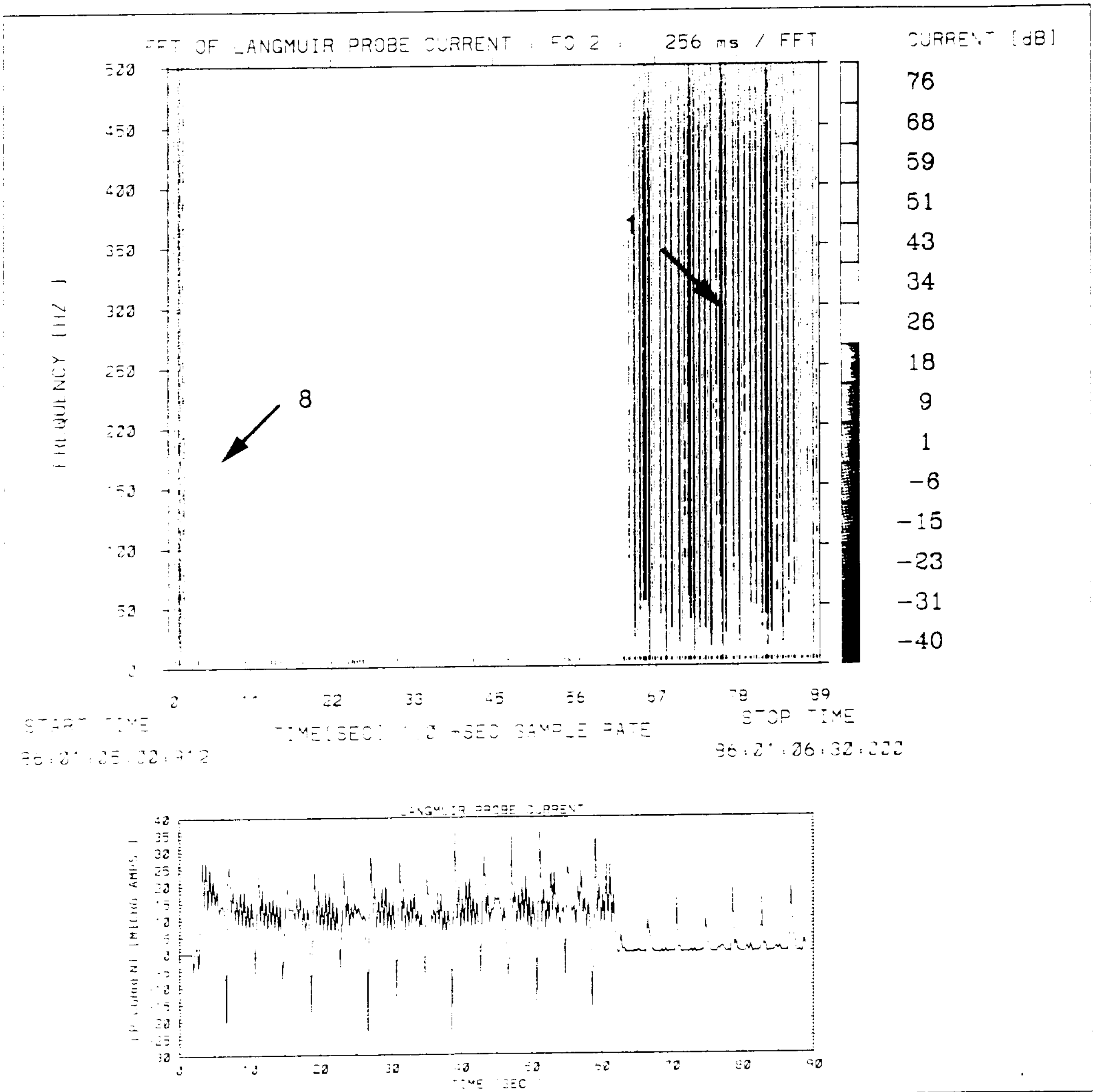


ATLAS-1 FO Ø2 IØ86/Ø1:Ø5: 2.5ØØ - Ø86/Ø1:Ø5:32.5ØØ)

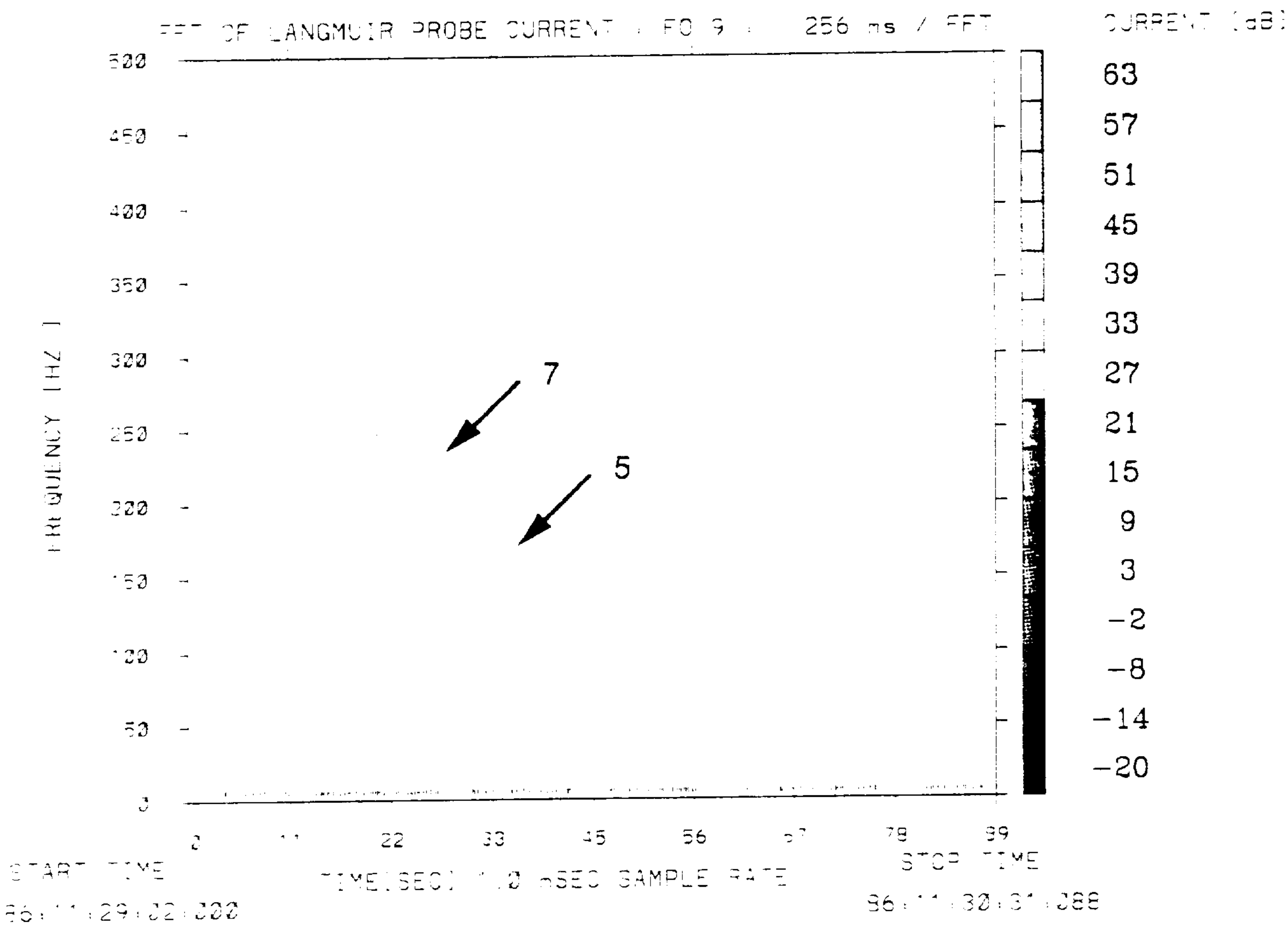




ORIGINAL PAGE IS
OF POOR QUALITY



ORIGINAL PAGE IS
OF POOR QUALITY


LANGMUIR PROBE CURRENT
256 ms / FFT
CURRENT (dB)
63
57
51
45
39
33
27
21
15
9
3
−2
−8
−14
−20
FREQUENCY (HZ)
500
450
400
350
300
250
200
150
100
50
7
5
22
33
45
56
78
89
START TIME
STOP TIME
SAMPLE RATE

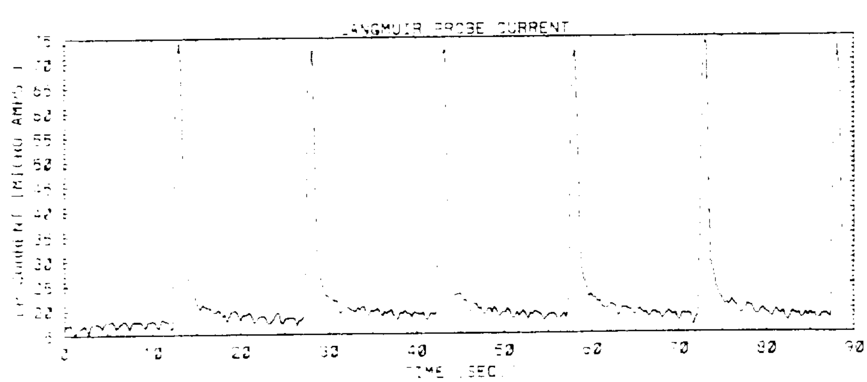

LANGMUIR PROBE CURRENT
20
30
40
50
80
90

Table of Plasma Wave Amplitudes

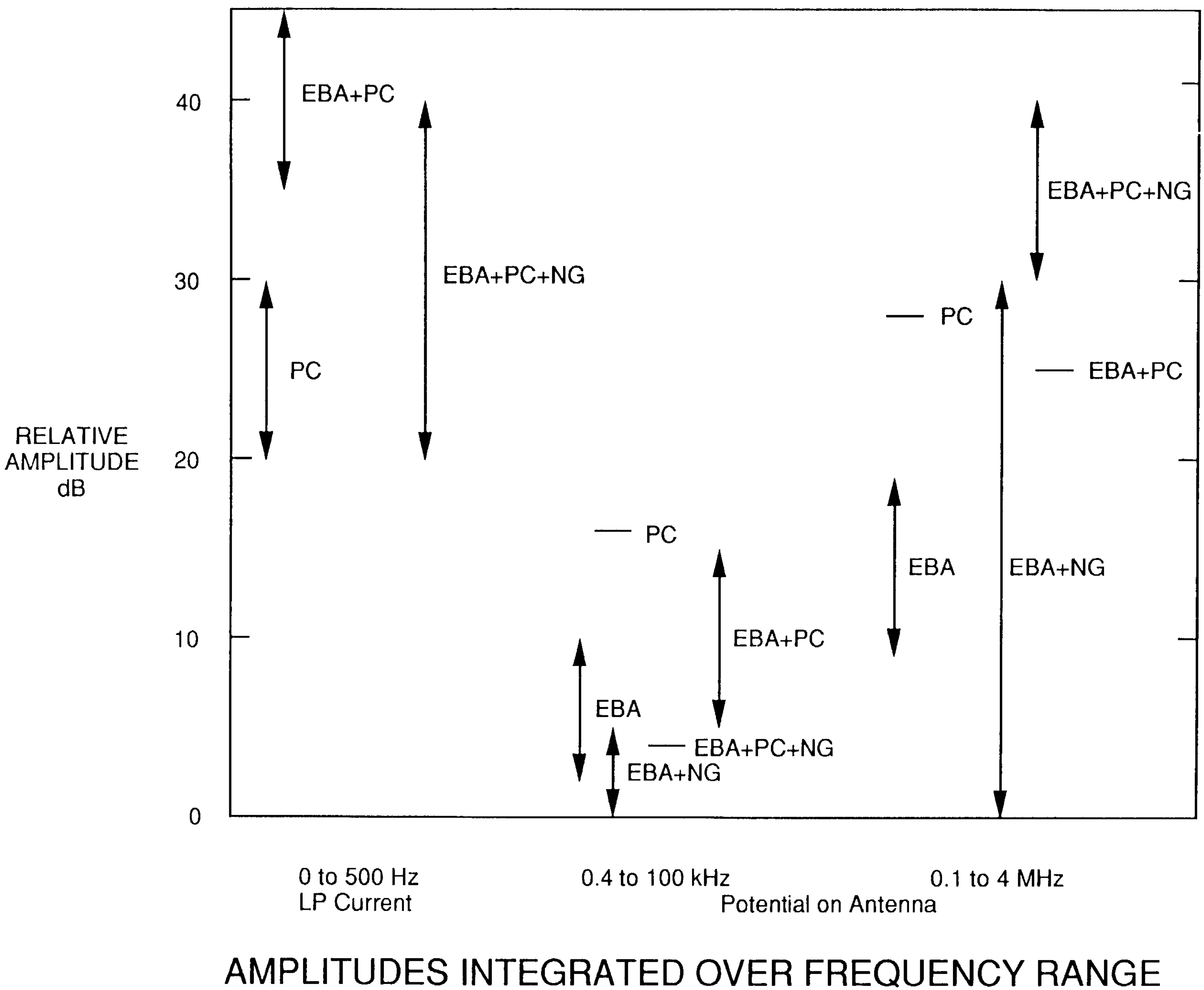
EFFECT OF ELECTRON BEAM, PLASMA CONTACTOR AND NEUTRAL GAS ON PLASMA WAVE AMPLITUDES

	EBA OFF: NG OFF	EBA OFF: NG ON	EBA ON: NG OFF	EBA ON: NG ON
PC OFF	1 **BASELINE** ULF - 0 dB VLF - 0 dB MF - 0 dB	2 experiment not performed during FO 2*	3 VLF - +2 to +10 dB MF - +8 to +15 dB	4 VLF - 0 to +5 dB MF - 0 to +30 dB
PC ON	5 ULF - +20 to +30dB VLF - +17 dB MF - +28 dB	6 experiment not performed	7 ULF - +35 to +45 dB VLF - +5 to +15 dB MF - +25 dB	8 ULF - +20 to +40 dB VLF - +4 dB MF - +30 to +40 dB

* See Marshall et al, paper SA 12A-3

ULF: 0 to 500 Hz VLF: 0.4 to 100 kHz MF: 0.1 to 4 MHz

Summary of Plasma Wave Amplitudes



CONCLUSIONS

TO MINIMIZE ULF WAVE AMPLITUDES AT THE HIGHEST ELECTRON BEAM CURRENTS, THE ORDER OF PREFERENCE OF NEUTRALIZATION TECHNIQUES FOR THE SEPAC ELECTRON BEAM

* PLASMA CONTACTOR AND NEUTRAL GAS
* PLASMA CONTACTOR

TO MINIMIZE VLF WAVE AMPLITUDES AT THE HIGHEST ELECTRON BEAM CURRENTS, THE ORDER OF PREFERENCE OF NEUTRALIZATION TECHNIQUES FOR THE SEPAC ELECTRON BEAM

* PLASMA CONTACTOR AND NEUTRAL GAS
* NEUTRAL GAS
* PLASMA CONTACTOR

TO MINIMIZE MF WAVE AMPLITUDES AT THE HIGHEST ELECTRON BEAM CURRENTS, THE ORDER OF PREFERENCE OF NEUTRALIZATION TECHNIQUES FOR THE SEPAC ELECTRON BEAM

* PLASMA CONTACTOR
* NEUTRAL GAS
* PLASMA CONTACTOR AND NEUTRAL GAS

NRC

VIRTUAL ANTENNAS: USES, RESULTS AND THE FUTURE

by William W. L. Taylor

NRC

Presented to:

INTERNATIONAL SYMPOSIUM ON

ELECTRON BEAM EXPERIMENT IN SPACE AND ITS APPLICATION

March 26-27, 1993

Atami, Japan

VIRTUAL ANTENNAS: USES, RESULTS AND THE FUTURE

ABSTRACT

William W. L. Taylor
Nichols Research Corporation
Arlington, VA, USA

Active experiments, although sparsely used in the first 35 years of space physics, have the potential of investigating the physical processes in space with controlled conditions. A typical active experiment is to determine the reaction of a physical system to the variation of a single parameter in a known way. The alternative, which has been the primary method of space physics, is to rely on nature to provide conditions which might help to unravel the physics of the system. Active experiments in space can use injection of charged or neutral particles or waves. Wave injection can be accomplished with transmitters and (real, physical) antennas or with virtual antennas, those using modulated beams of charged particles. Like electrons in metal antennas, electrons or ions guided by magnetic field lines will radiate electromagnetic waves. In plasmas like the ionosphere these electromagnetic waves are called plasma waves and interact strongly with the ionospheric plasma.

Few virtual antenna experiments have been performed; most have been to test their efficiencies. Almost all instruments to perform virtual antenna experiments have been on sounding rockets and shuttle/spacelab flights. A notable exception is APEX, an international project which includes a Russian satellite with a powerful electron beam which can be modulated and a Czechoslovakian subsatellite instrumented with plasma and plasma wave instrumentation.

Theoretical treatments of virtual antennas have reached inconsistent conclusions. This is not surprising since the physical system to be analyzed is very complicated and several theoretical techniques have been used. A major unknown is the total current system created by the particle beam.

The next objectives for virtual antennas are to fully understand their properties, to determine how to effectively use them in space, and to fully utilize them in an experimental program to investigate wave particle interactions in the ionosphere and the magnetosphere. Meeting those objectives will require a long lived platform with adequate resources. Such a platform could be the space station now being designed by the US, Japan, ESA and Canada.

Atami, Japan

ACTIVE EXPERIMENTS IN SPACE

First phase of understanding is observation

- Space research used for 30+ years

Other phases

- Experiment
  - Modifying the physical system - lightly used for 25+ years
  - Simulation - becoming very popular
- Theory and modeling

ACTIVE EXPERIMENTS - TYPES

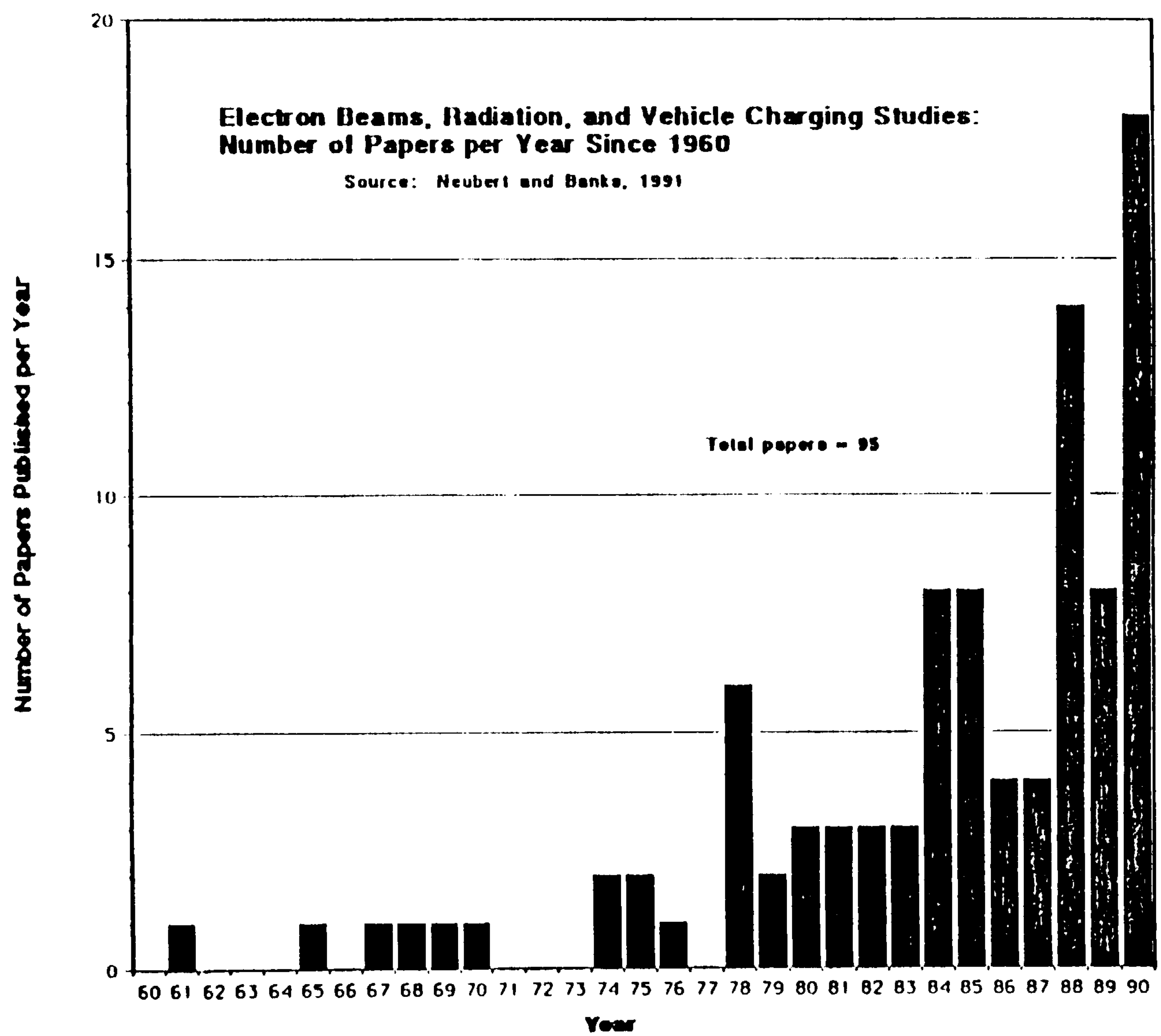
Charged Particle Injection

- Argus
- Hess experiments
- ECHO series
- SEPAC

Mass Injection

- Air Force Cambridge Research Labs
- CRRES

Wave Injection



Electron Beams, Radiation, and Vehicle Charging Studies:
Number of Papers per Year Since 1960
Source: Neubert and Banks, 1991
Total papers = 95
Number of Papers Published per Year
0
5
10
15
20
60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90
Year

WAVE INJECTION

From the ground

- Ionosondes
- Radar
- Transmitters

From space

- Types of transmitters
  - Antennas
  - Virtual Antennas

WAVE INJECTION - ANTENNAS

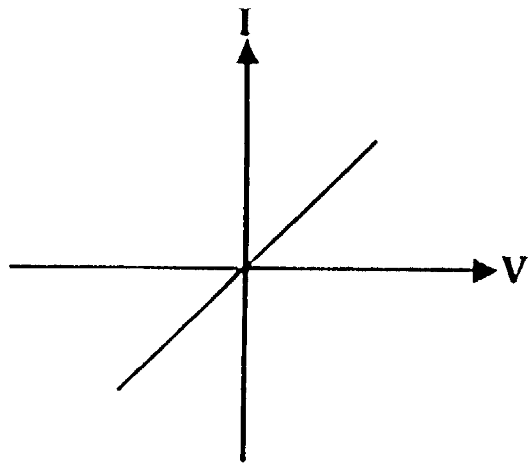
Topside sounders

- Alouette/ISIS Series
- Akebono (EXOS - D)
- Oedipus - A
- WISP/HF

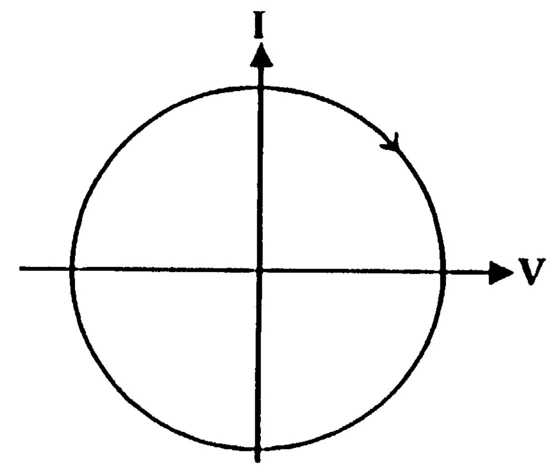
Transmitters

- Impedance measurements
- WISP, Space Plasma Lab, Sounding Rockets
- ACTIVE

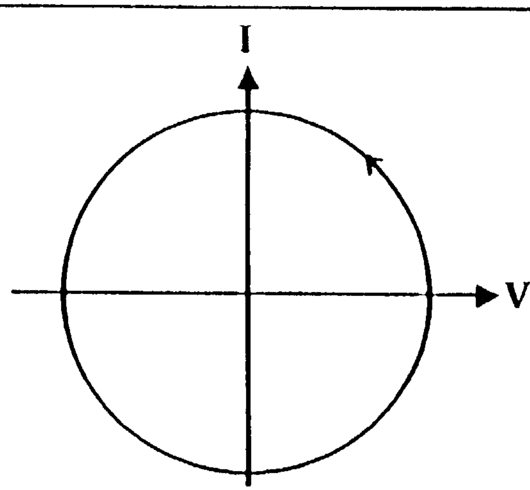
SOME TYPES OF DATA EXPECTED



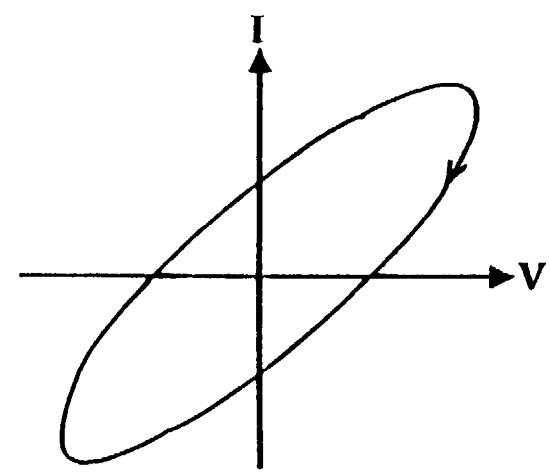
Restistive - $\varnothing = 0^{\circ}$



Capacitive - $\varnothing = -90^{\circ}$



Inductive - $\varnothing = +90^{\circ}$



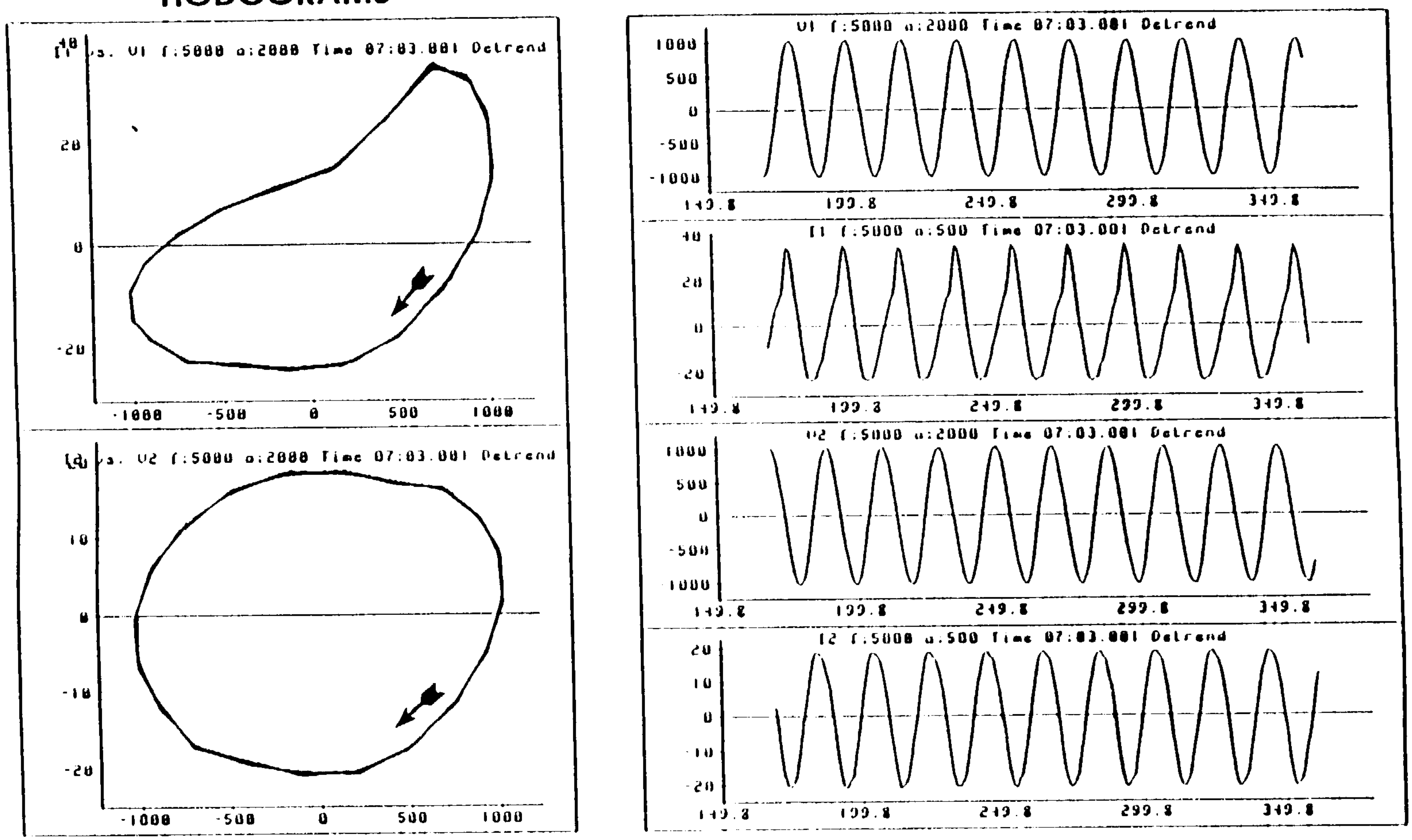
R,C - $\varnothing = -45^{\circ}$

WISP/ROCKET VOLTAGE/CURRENT DISPLAYS

TRW

HODOGRAMS

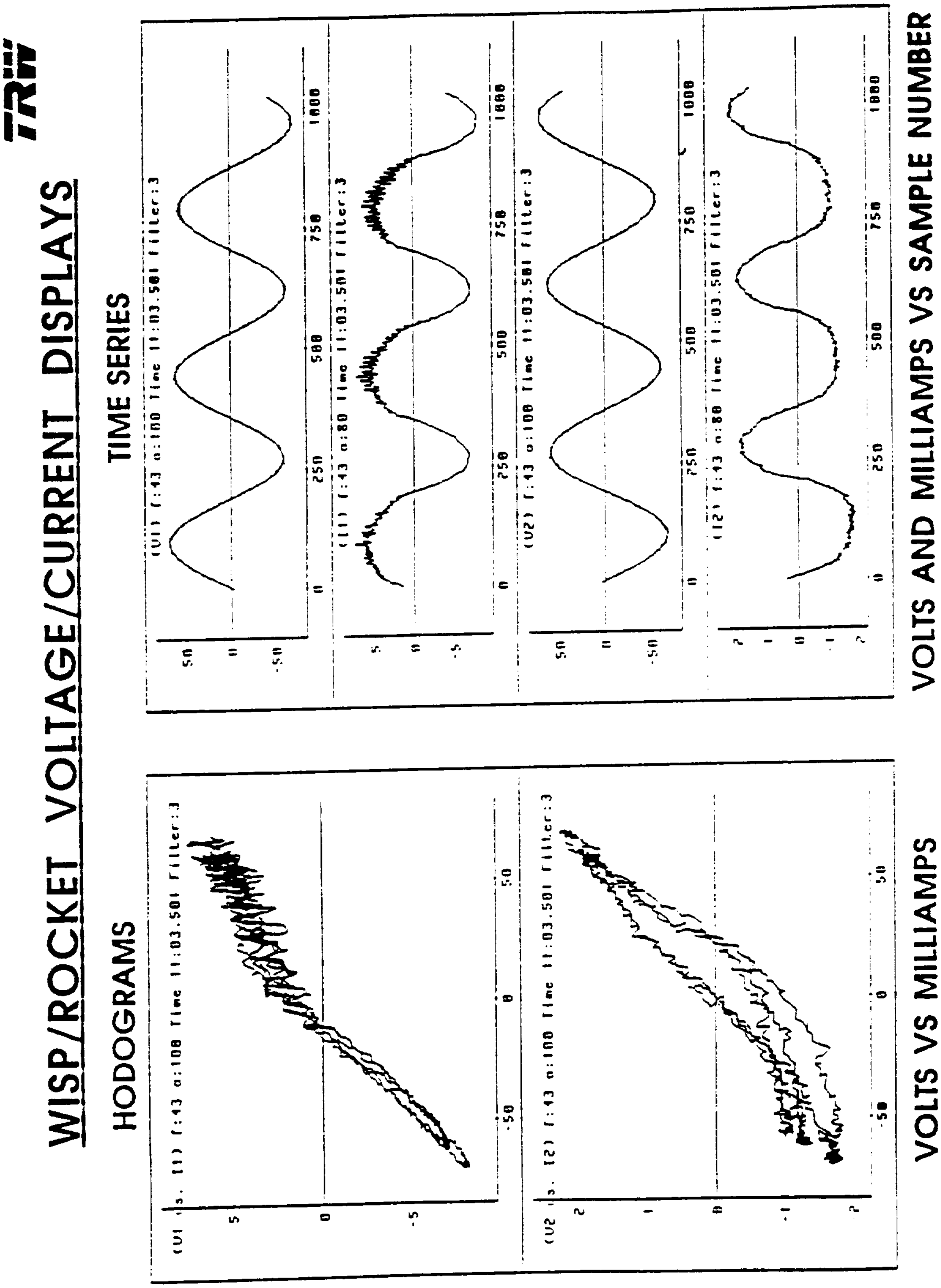
TIME SERIES



VOLTS VS MILLIAMPS

VOLTS AND MILLIAMPS VS SAMPLE NUMBER

Figure 1.

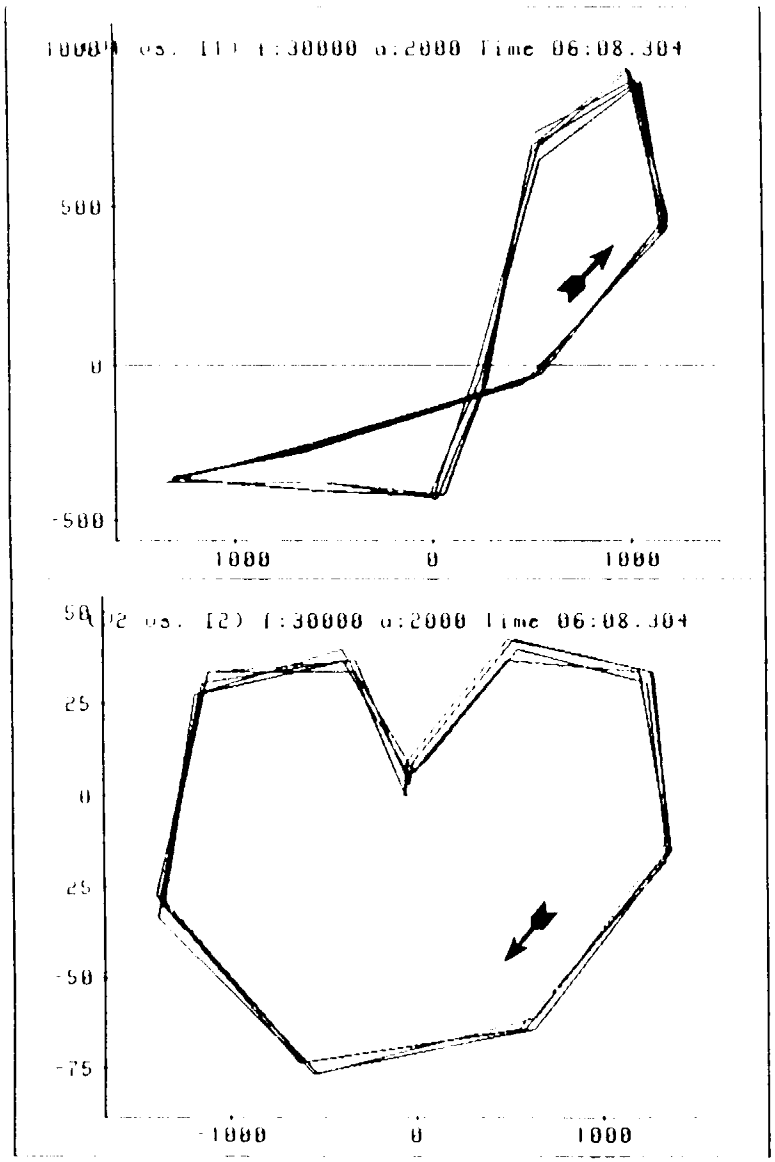


TRW
WISP/ROCKET VOLTAGE/CURRENT DISPLAYS
HODOGRAMS
VOLTS VS MILLIAMPS
TIME SERIES
VOLTS AND MILLIAMPS VS SAMPLE NUMBER

Figure 2.

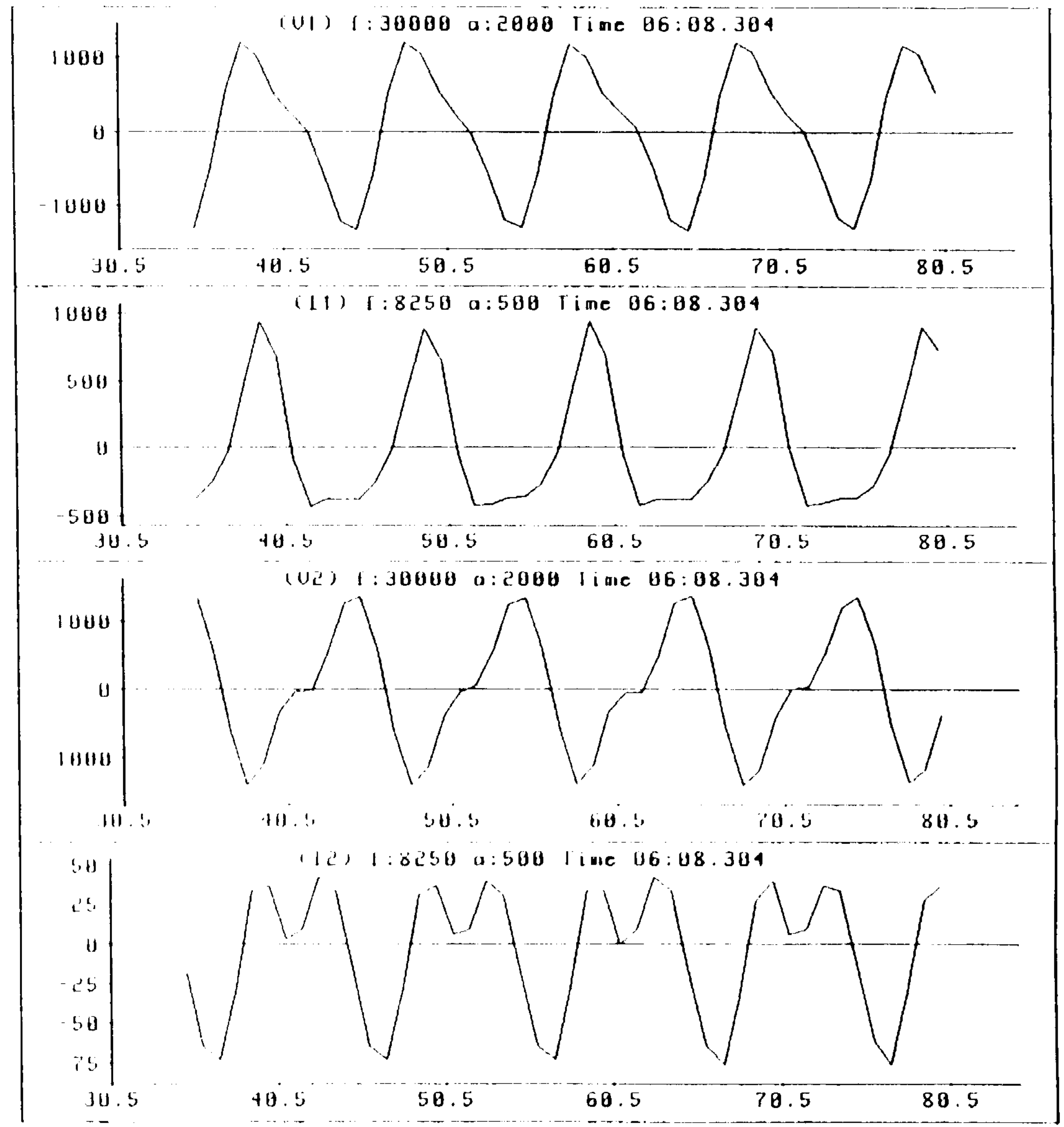
WISP/ROCKET VOLTAGE/CURRENT DISPLAYS

HODOGRAMS



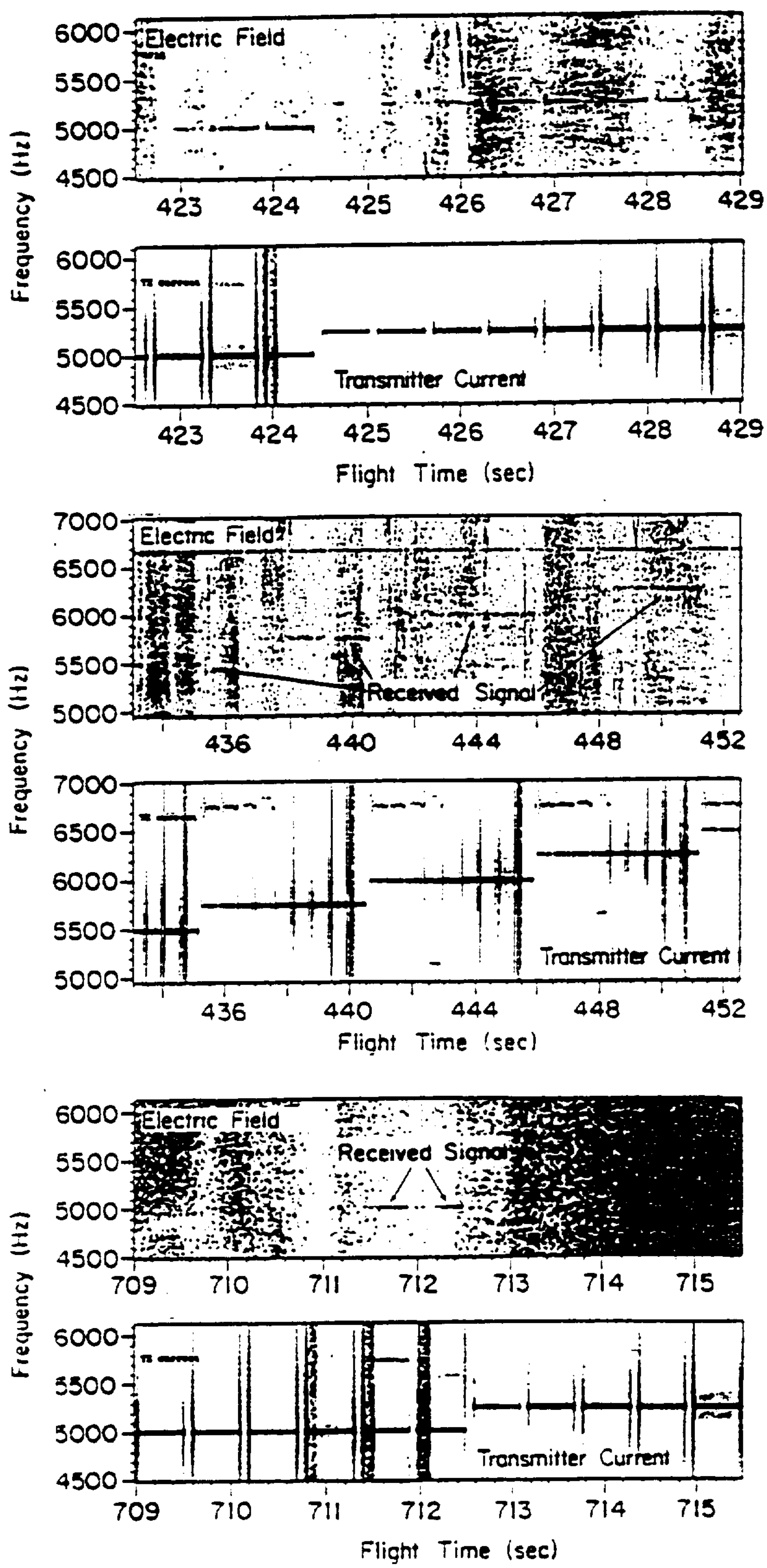
VOLTS VS MILLIAMPS

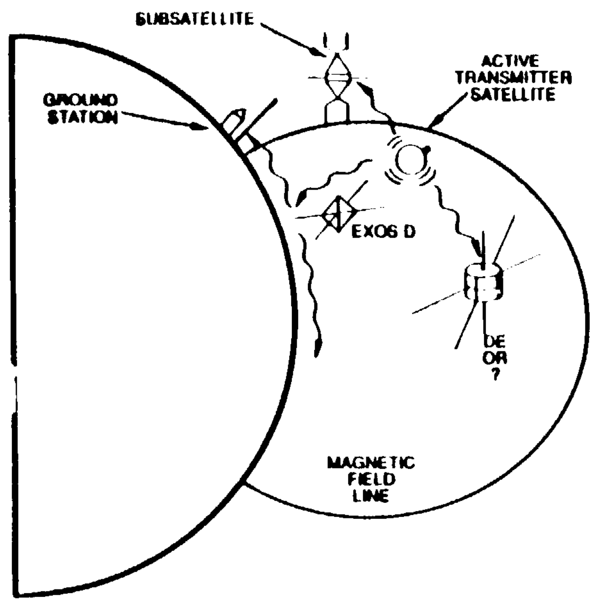
TIME SERIES



VOLTS AND MILLIAMPS VS SAMPLE NUMBER

WISP 1


Electric Field
Transmitter Current
Frequency (Hz)
Flight Time (sec)
6000
5500
5000
4500
423
424
425
426
427
428
429
Electric Field
Received Signal
Transmitter Current
Frequency (Hz)
Flight Time (sec)
7000
6500
6000
5500
5000
436
440
444
448
452
Electric Field
Received Signal
Transmitter Current
Frequency (Hz)
Flight Time (sec)
6000
5500
5000
4500
709
710
711
712
713
714
715



- o TWO SATELLITE IONOSPHERIC MISSION TO PROBE AND PERTURB PLASMA
- o 500 KM BY 2500 KM BY 82.5° ORBIT
- o POWERFUL TRANSMITTER AT 9.6 kHz
  - 5 kW AMPLIFIER
  - 20 M LOOP ANTENNA
- o RECEIVERS
  - ON TRANSMITTER SATELLITE
  - ON RECEIVER SUBSATELLITE
  - ON THE GROUND

INTERNATIONAL SCIENTIFIC TEAM

USSR

- o IKI, PROJECT LEADERSHIP, TRANSMITTER SATELLITE

CZECHOSLOVAKIA

- o GEOPHYSICAL INSTITUTE, SUBSATELLITE

OTHERS

- o POLAND
- o HUNGARY
- o GDR
- o BULGARIA
- o CUBA
- o USA
- o JAPAN
- o FINLAND
- o BRAZIL
- o CANADA
- o ENGLAND

SCIENTIFIC OBJECTIVES

- o ANTENNA PROPERTIES
- o NEAR ZONE (FIELD) STUDIES
- o WAVE PROPAGATION
- o WAVE PARTICLE INTERACTIONS
- o NONLINEAR EFFECTS
- o CRITICAL IONIZATION VELOCITY
- o ION BEAM-PLASMA INTERACTIONS

WAVE INJECTION - VA

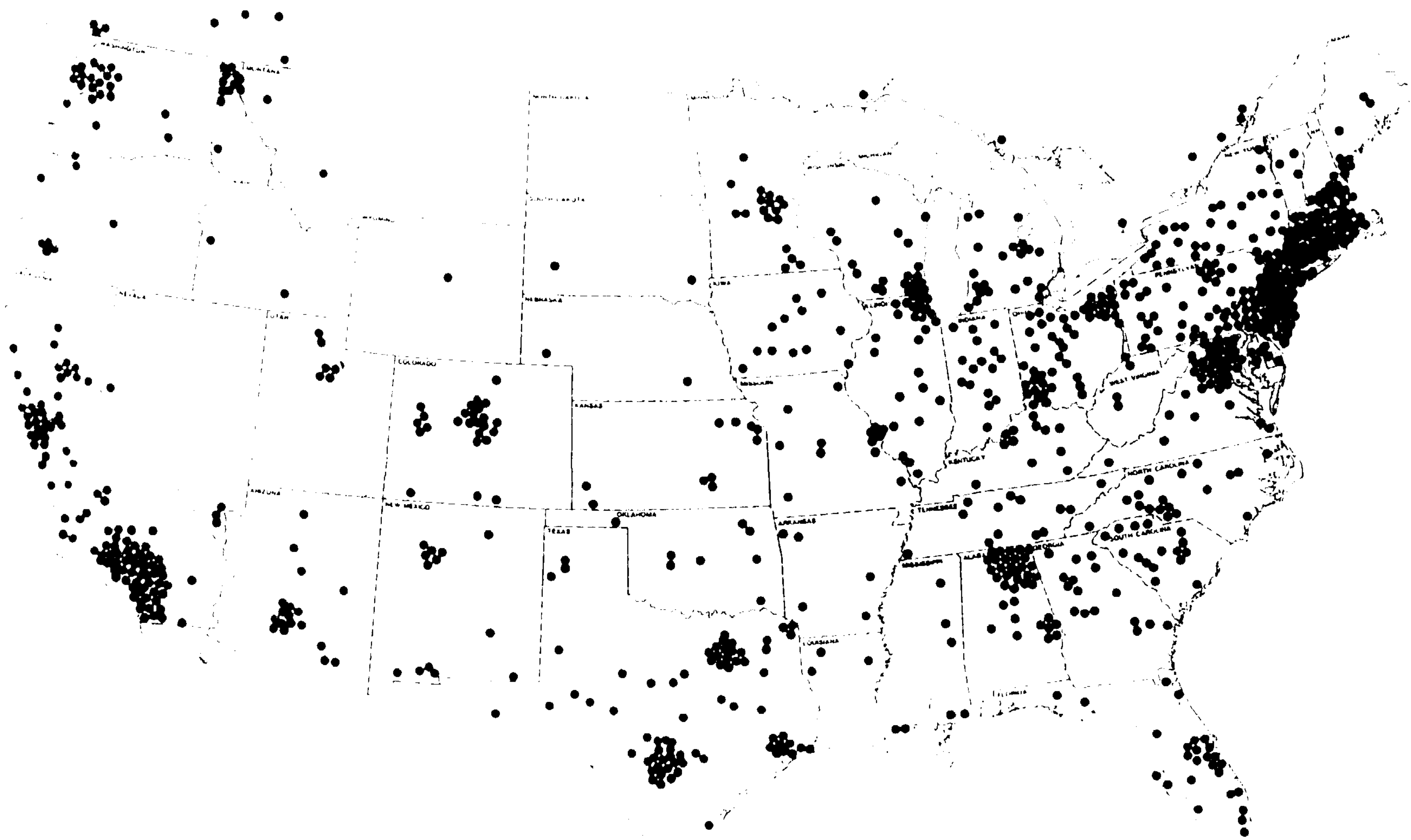
ECHO

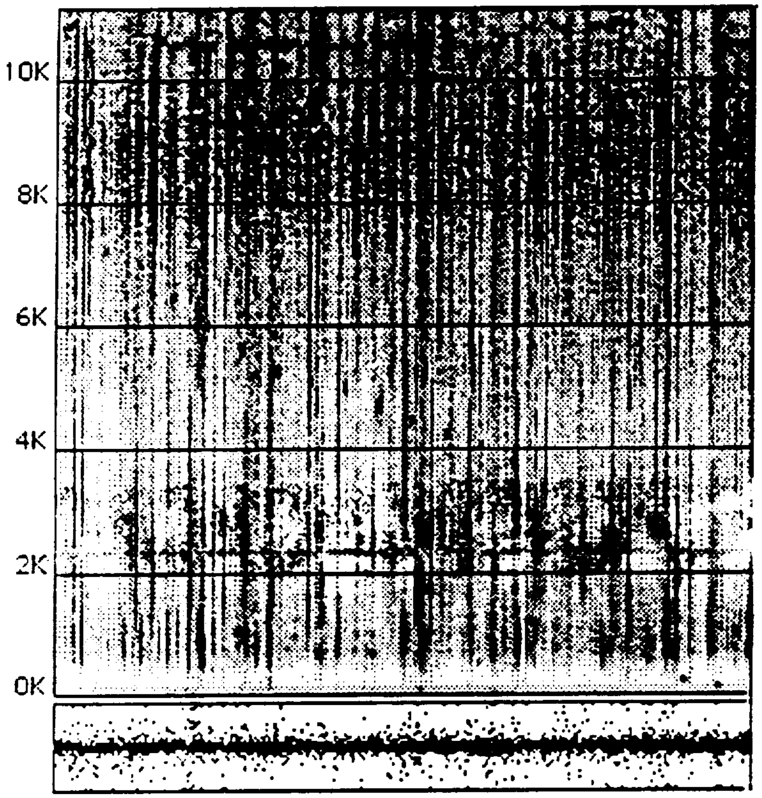
FPEG/PDP

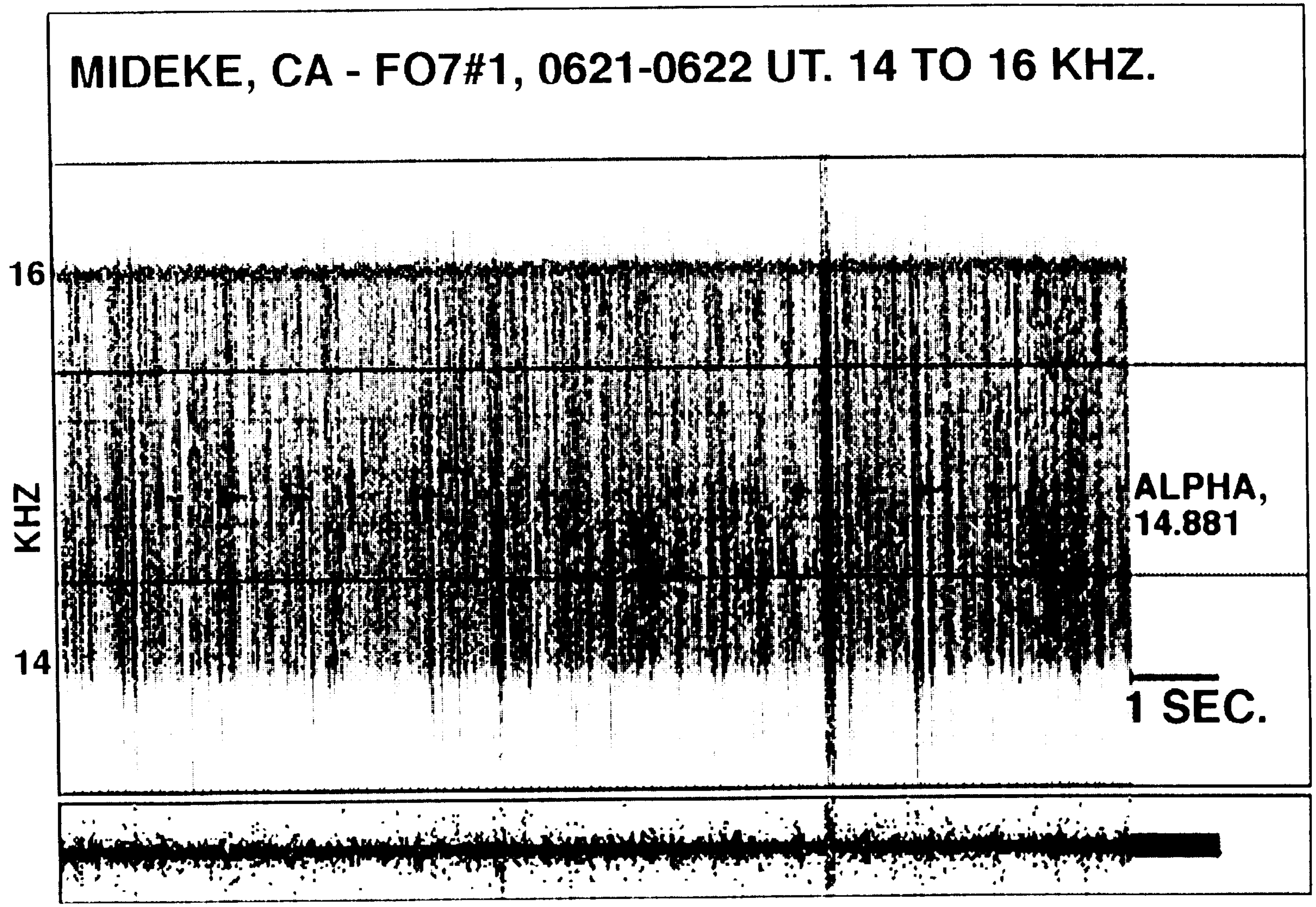
APEX

SEPAC

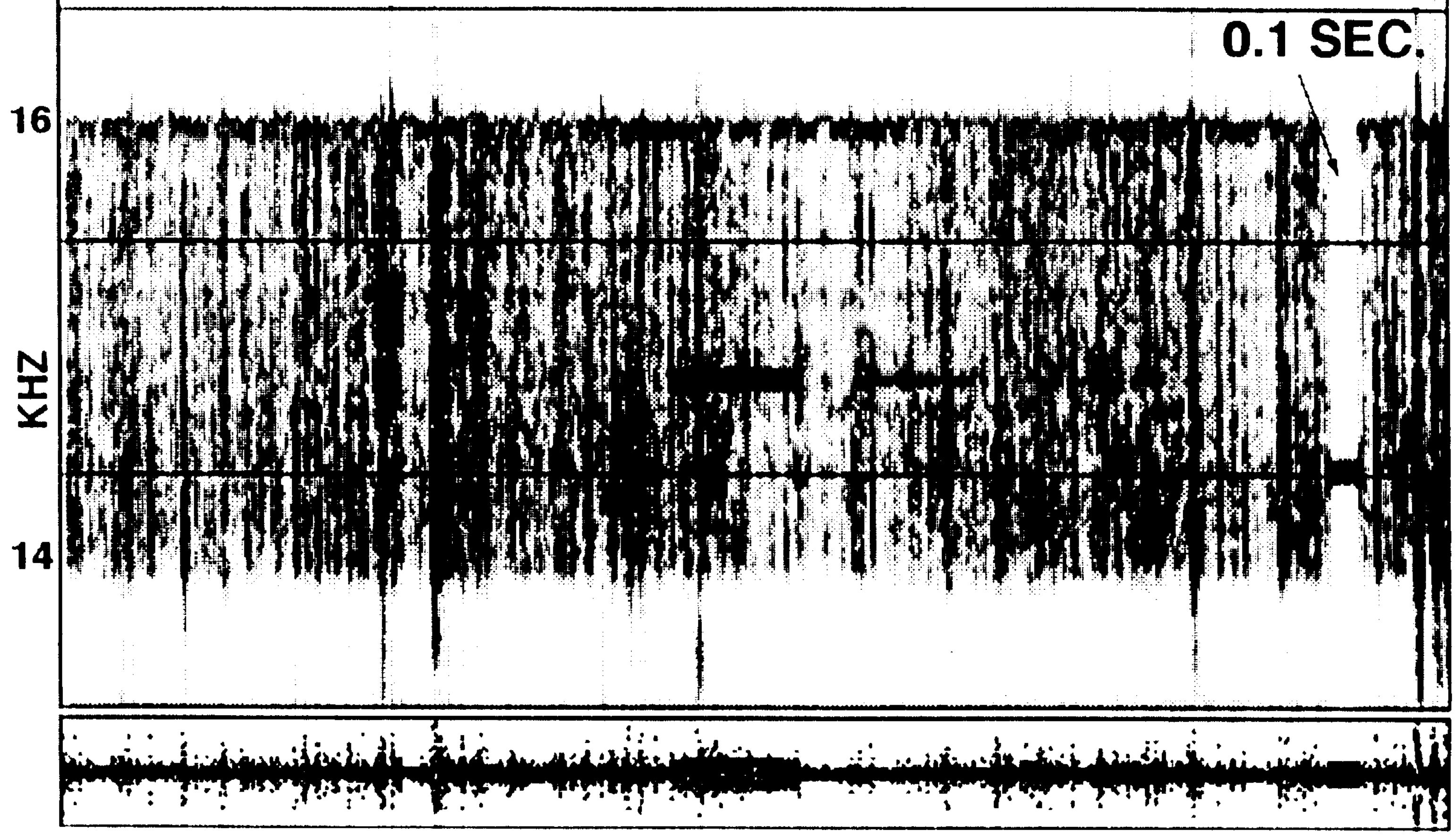
1000 OBSERVING SITES FOR INSPIRE






MIDEKE, CA - FO7#1, 0621-0622 UT. 14 TO 16 KHZ.
16
KHZ
14
ALPHA,
14.881
1 SEC.

MIDEKE, CA - FO7#1 FROM 0621 UT. 14 TO 16 KHZ.

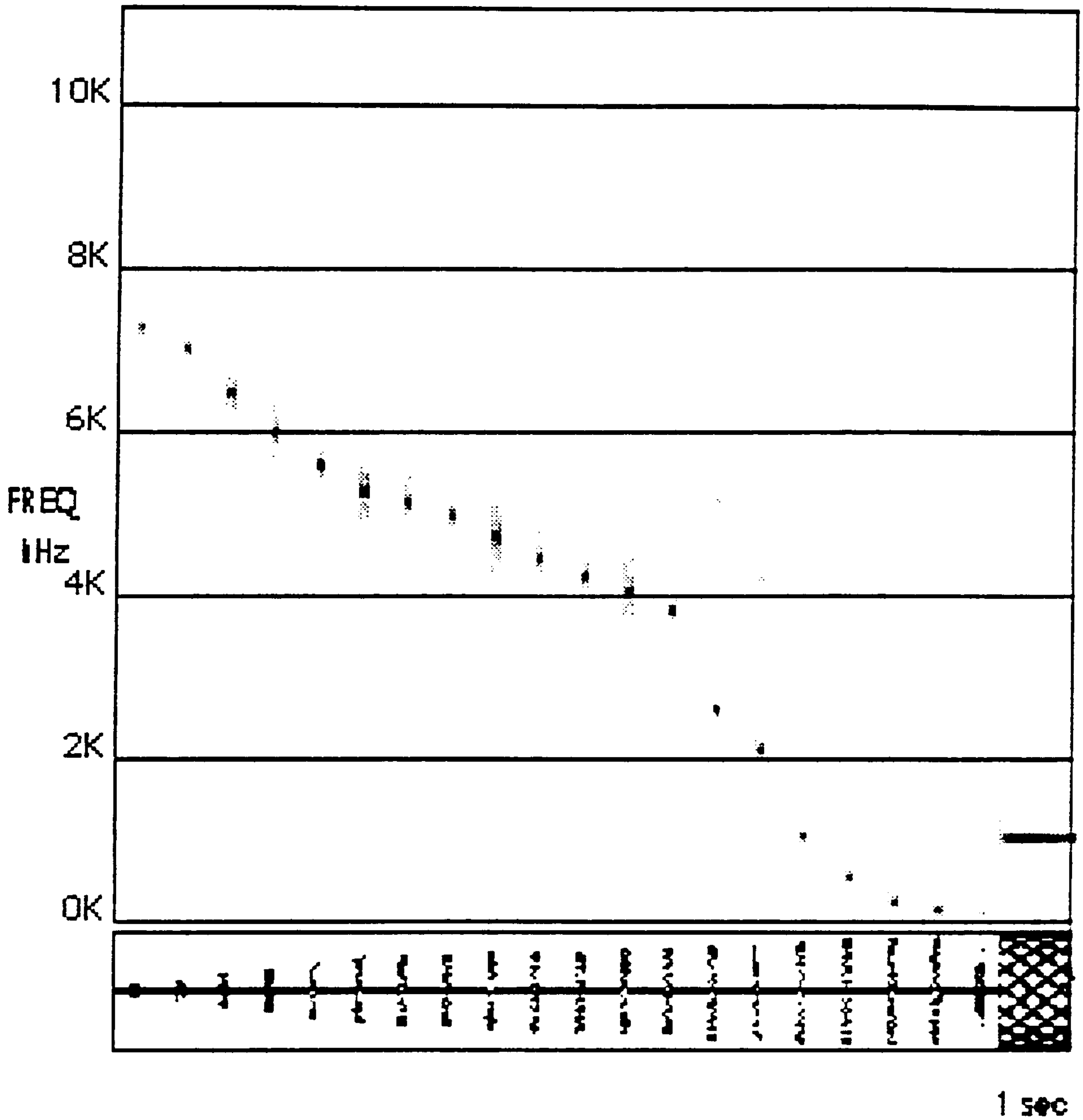


INSPIRE OBJECTIVES

- Determine electromagnetic wave propagation from SEPAC to the earth
  - Establish an array of receiving stations
- Provide opportunitity for high school students to participate in NASA project to perform publishable scientific experiment in space
- Enable high schools to acquire very low frequency receivers
- Allow continuing observations and studies of naturally occurring and man-made phenomena

INSPIRE WILL ENHANCE SEPAC SCIENCE

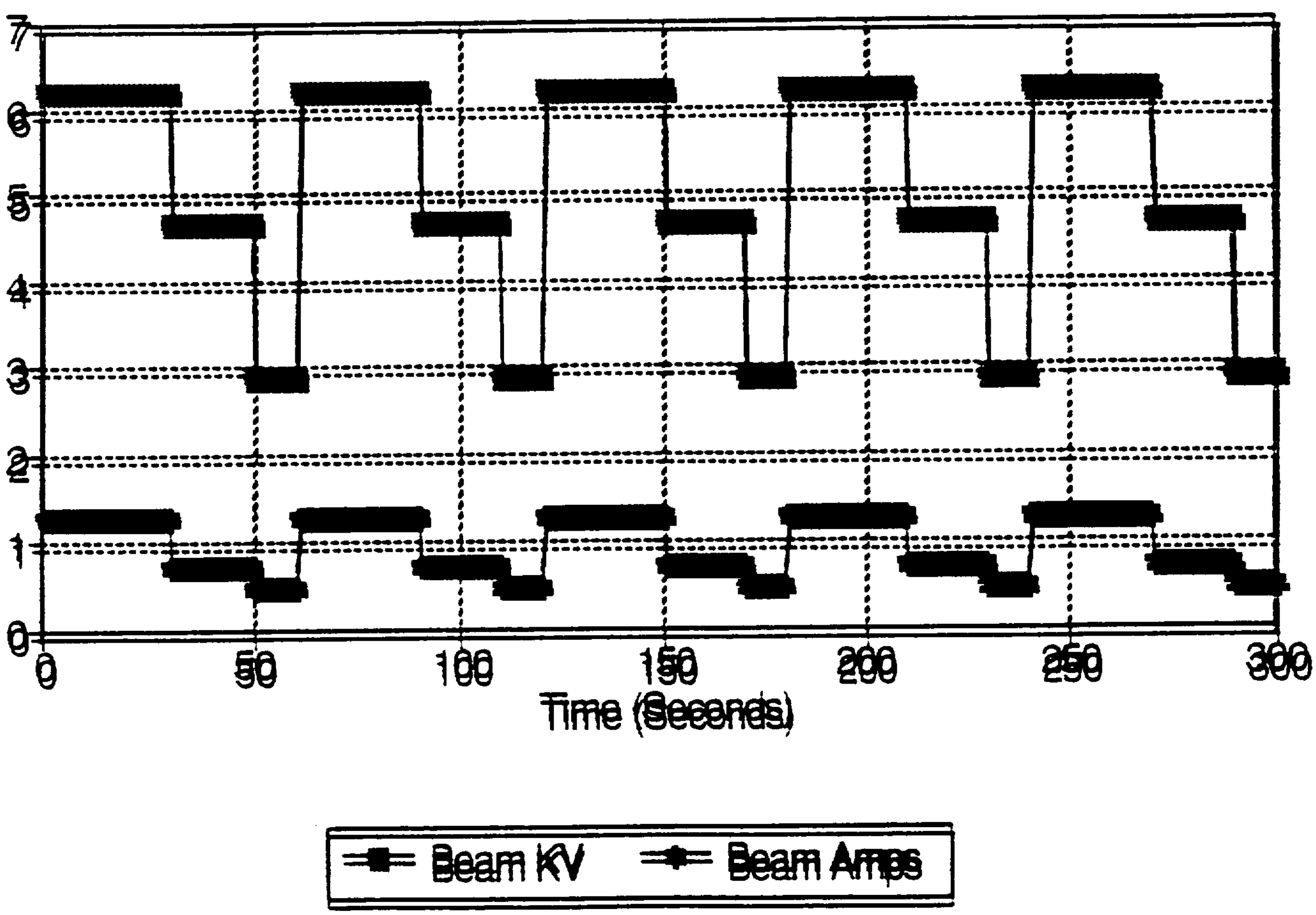
- SEPAC will emit pulsed electron beam (50 Hz - 7 kHz)
- Beam will create electromagnetic waves
- Electromagnetic waves will propagate through ionosphere and atmosphere
- Students will receive and record waves on cassette recorders
- Data will be analyzed by classes or INSPIRE project
- Results will be the basis of scientific papers



10K
8K
6K
FREQ
kHz
4K
2K
0K
1 sec

FO#7 Virtual Antenna

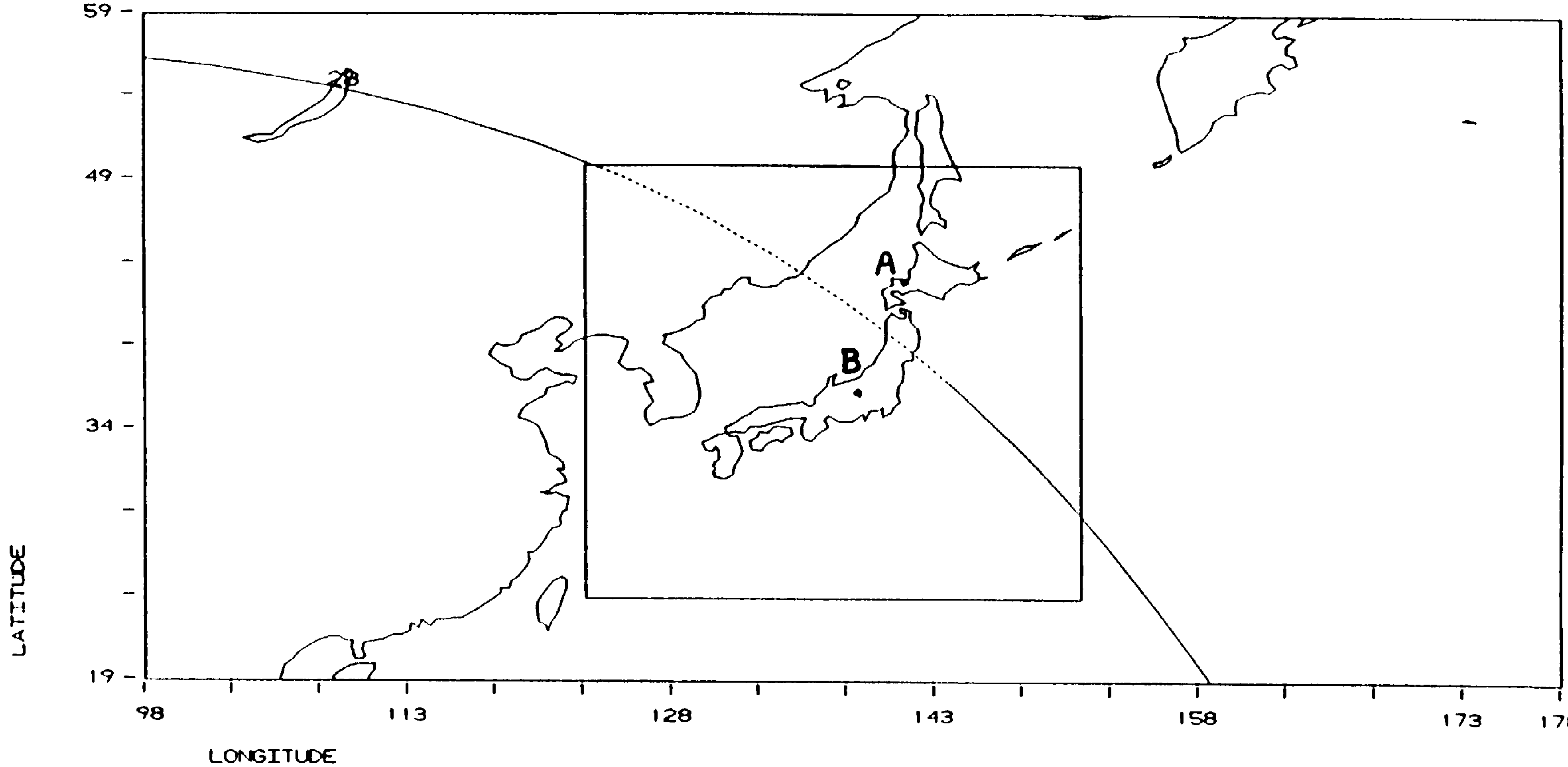
Beam Firings



GROUND TRACK ATLAS 1
40.00 TO 42.00 HOURS

..... JAPAN

OES PLOT GENERATED
25-MAR-92 17:58:39

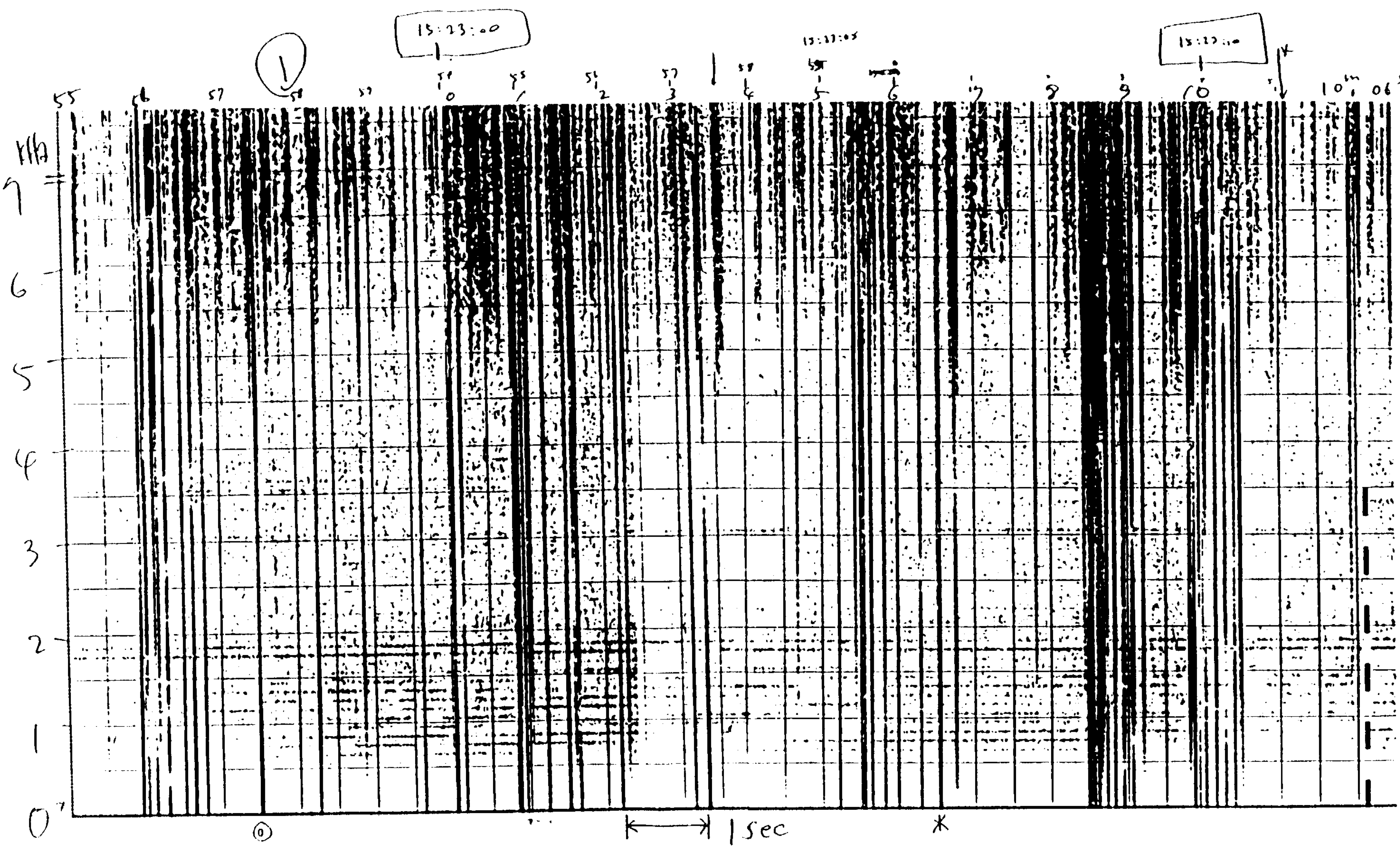


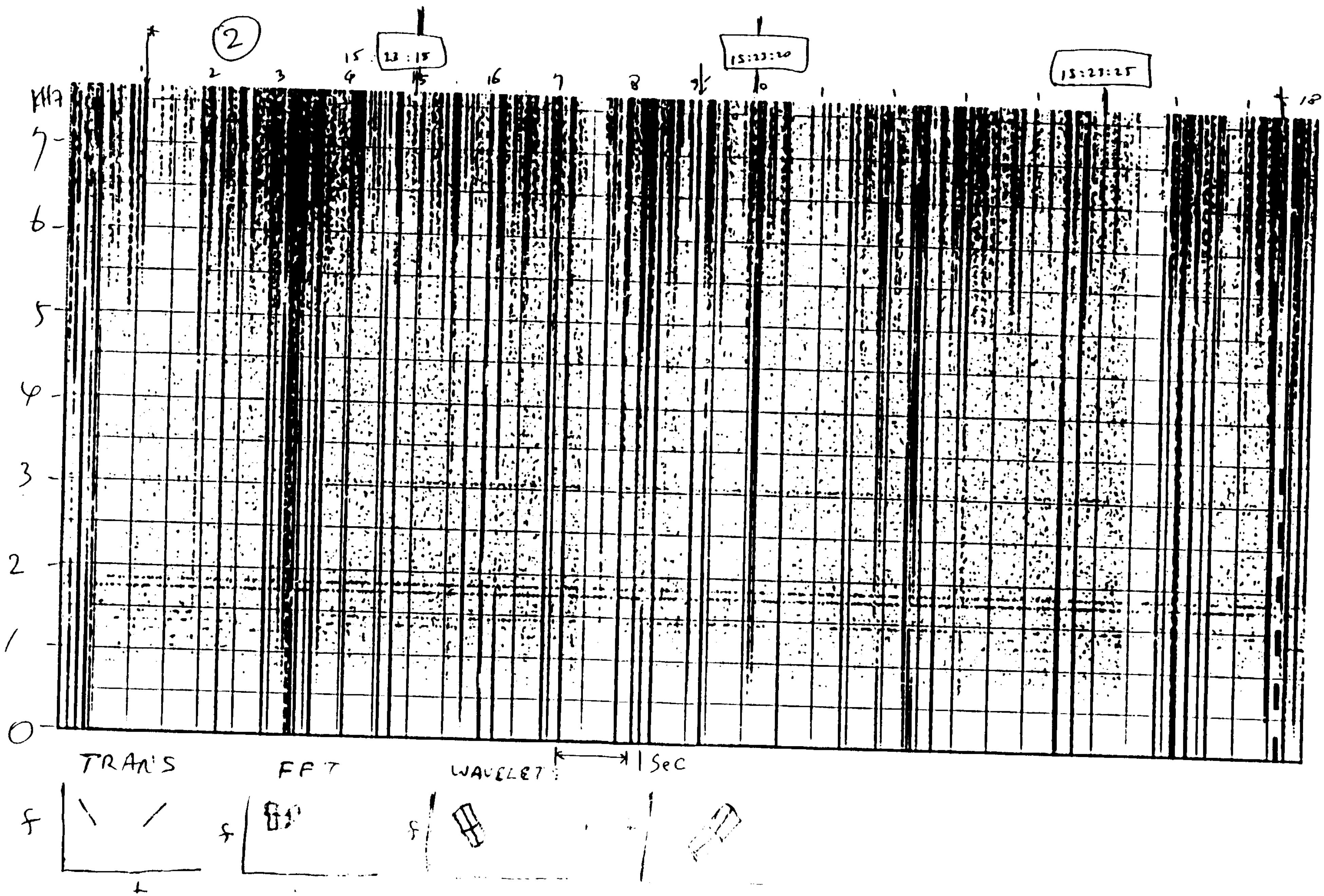
電子ビーム放射予定

	REV NO.	SEPAC 7 OPERATION TIME MET ON (D/H:M:S)	MET OFF	DUR(M:S)
	28	01/17:05:57	01/17:10:57	04:59
		24 07 13 30	24 07 13 30	
米国CST		26 00 19 27	26 00 24 27	
		24 22 13 30	24 22 13 30	
日本時間 (JST)		26 15 19 27 ~	26 15 24 27	

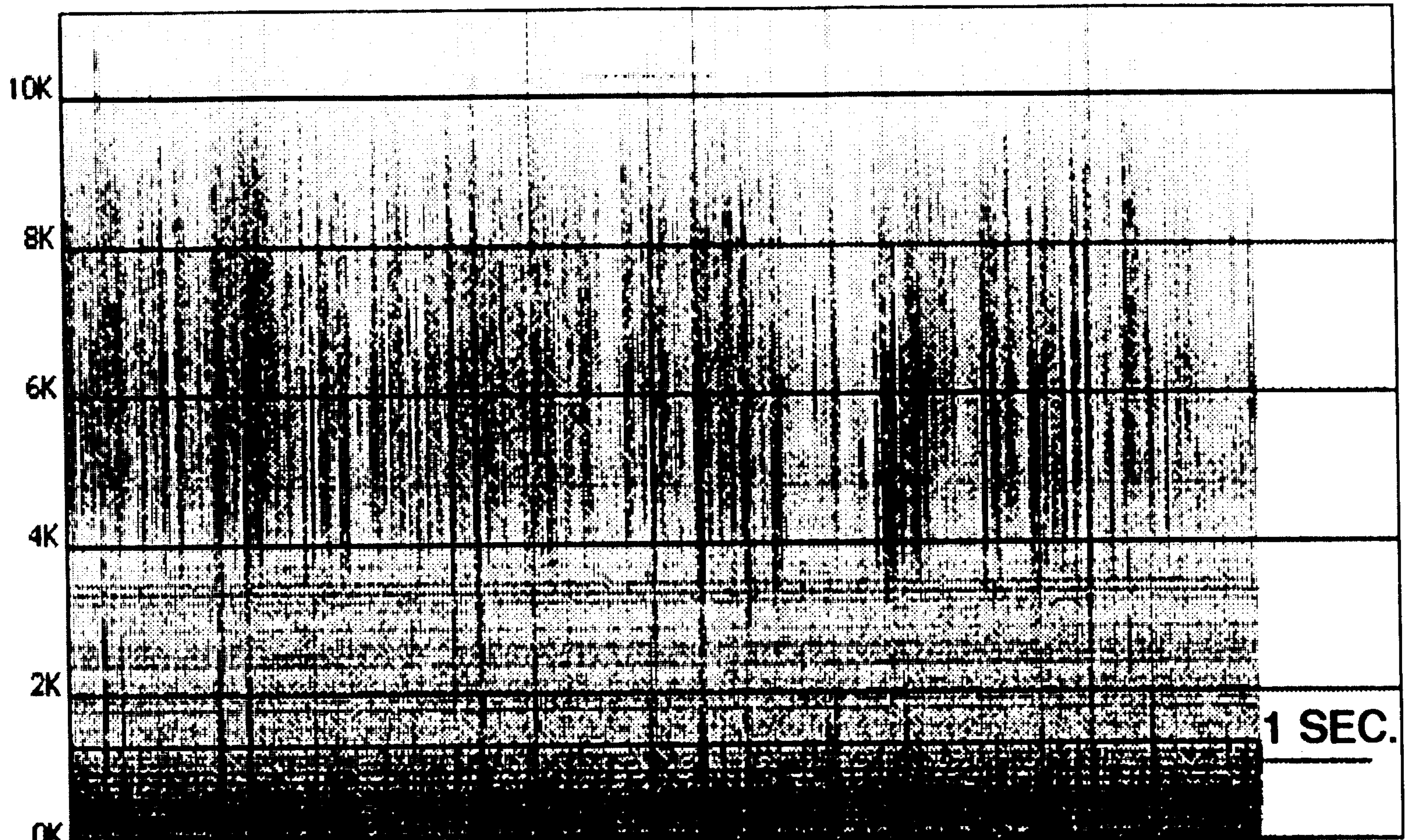
A : Hokkaido
B : Usuda

Location A

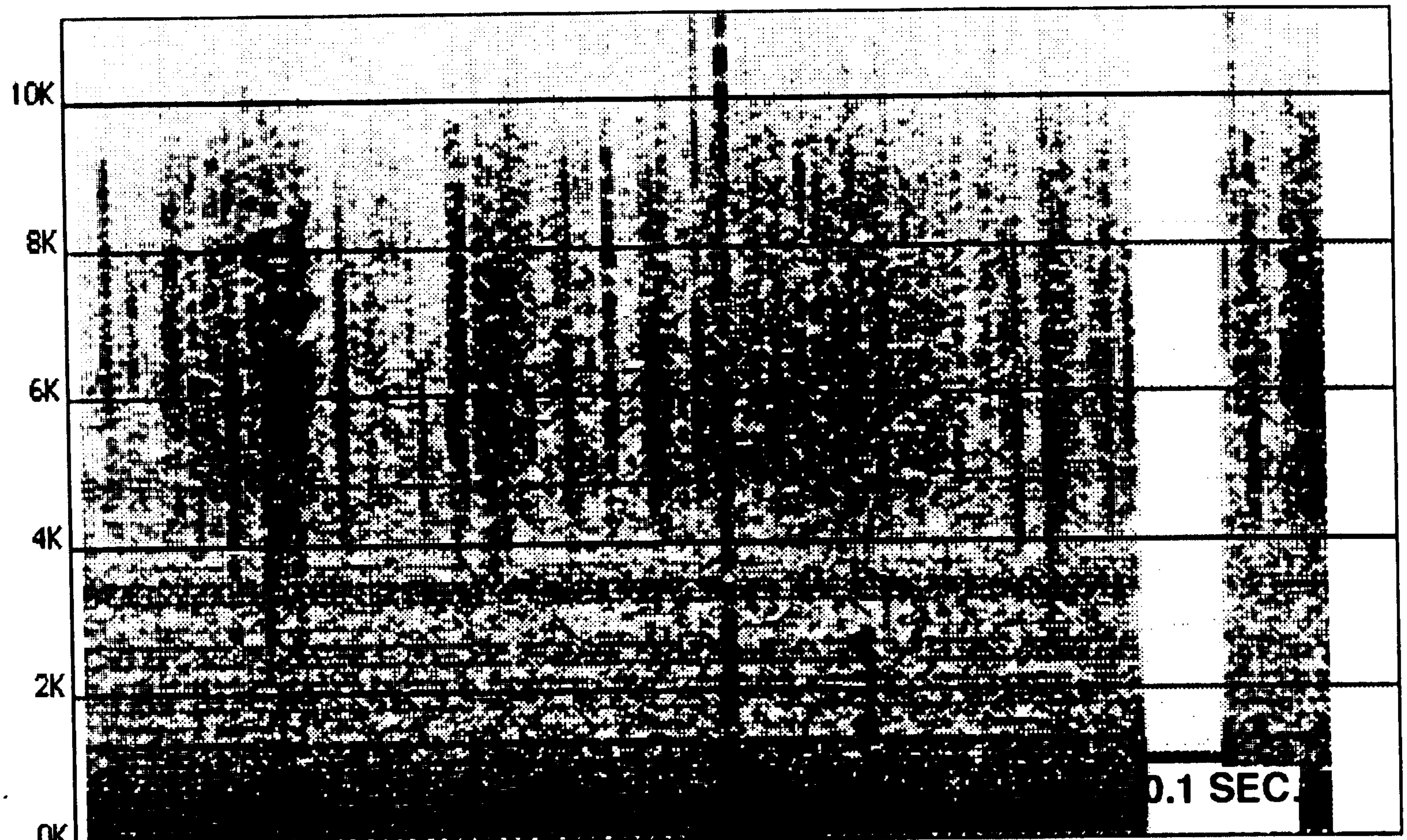




2
15 : 23 : 15
15:23:20
15:23:25
KHz
7
6
5
4
3
2
1
0
TRANS
FFT
WAVELET
1 Sec
f
t



GRIFFIN, CT - FO7#2 FROM ~1956 UT.



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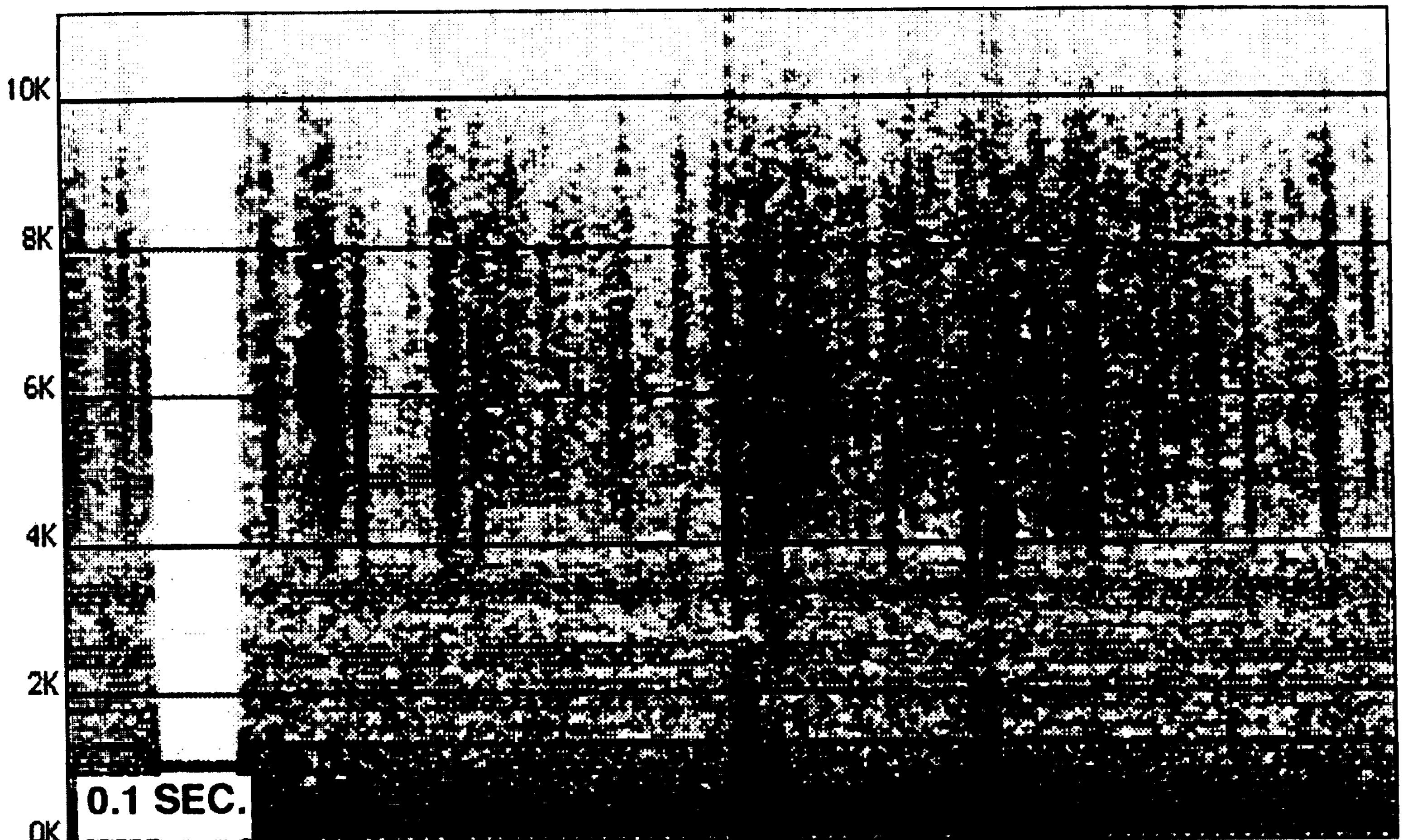

GRIFFIN, CT - FO7#2 FROM ~1956:013 UT.

NRC

Beam Plasma Interactions Stimulated by SEPAC on ATLAS 1: Wave Observations

by

William W. L. Taylor, NRC; Stewart L. Moses, TRW;
Torsten Neubert and Srikanth Raganatan, U. of Mich.

Presented at:
Session HG1. Active Experiments in Space

of
XXIVth General Assembly of the
International Union of Radio Science

Kyoto, Japan

August 25 - September 2, 1993

Beam Plasma Interactions Stimulated by SEPAC on ATLAS 1: Wave Observations

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TRW
Redondo Beach, CA 90278 USA

Torsten Neubert and Srikanth Ranganatan
University of Michigan
Ann Arbor, MI 48109 USA

Background

SEPAC (Space Experiments with Particle ACcelerators) flew on the ATLAS-1 (ATmospheric Laboratory for Applications and Science -1) Shuttle/Spacelab mission in March and April, 1992. SEPAC equipment included an electron accelerator, a plasma contactor for charge neutralization, and diagnostics. The electron accelerator ejected beams of electrons at energies up to 6.25 keV with currents up to 1.2 Amps. The diagnostics included a set of plasma wave instruments for measuring electric fields in the payload bay at frequencies from below 100 Hz to 10 MHz. A major objective of the SEPAC flight was to investigate the interactions between the electron beam and the ionosphere. The interactions were expected to include generation of plasma waves, and this expectation was fulfilled.

Measurements, Results, and Conclusions

Beam-plasma interaction experiments were conducted during 9 different time periods during the flight. During several of the experiments, the plasma contactor also operated. The plasma contactor was used to neutralize the shuttle during electron beam operations, which insured that the electron beam would be emitted at the expected energy and current. It has been reported earlier [1] that the operation of the plasma contactor increased the ambient noise level in the payload bay by 20-45 dB at frequencies of 0 to 500 Hz, by 5-17 dB at frequencies of 0.1 to 100 kHz and 25-28 dB at frequencies from 0.1 to 4 MHz.

Observations of plasma waves were made by floating probes, by sweep frequency receivers, and by wideband receivers for a variety of beam energies and currents, up to the maximums. The observations were made for times when the plasma contactor was operating and when it was not. Examples of the observations and analysis of their implications will be presented.

Besides making electron beam injection possible at the higher beam currents for making artificial aurora, the plasma contactor also masked the generation of plasma waves from the electron beam, since it generated high levels of plasma waves on its own.

Reference

[1] Taylor, W. W. L., S. L. Moses, T. Neubert, and S. Ranganatan, *EOS Trans. Amer. Geophys. Union, 73*, 413, 1992.

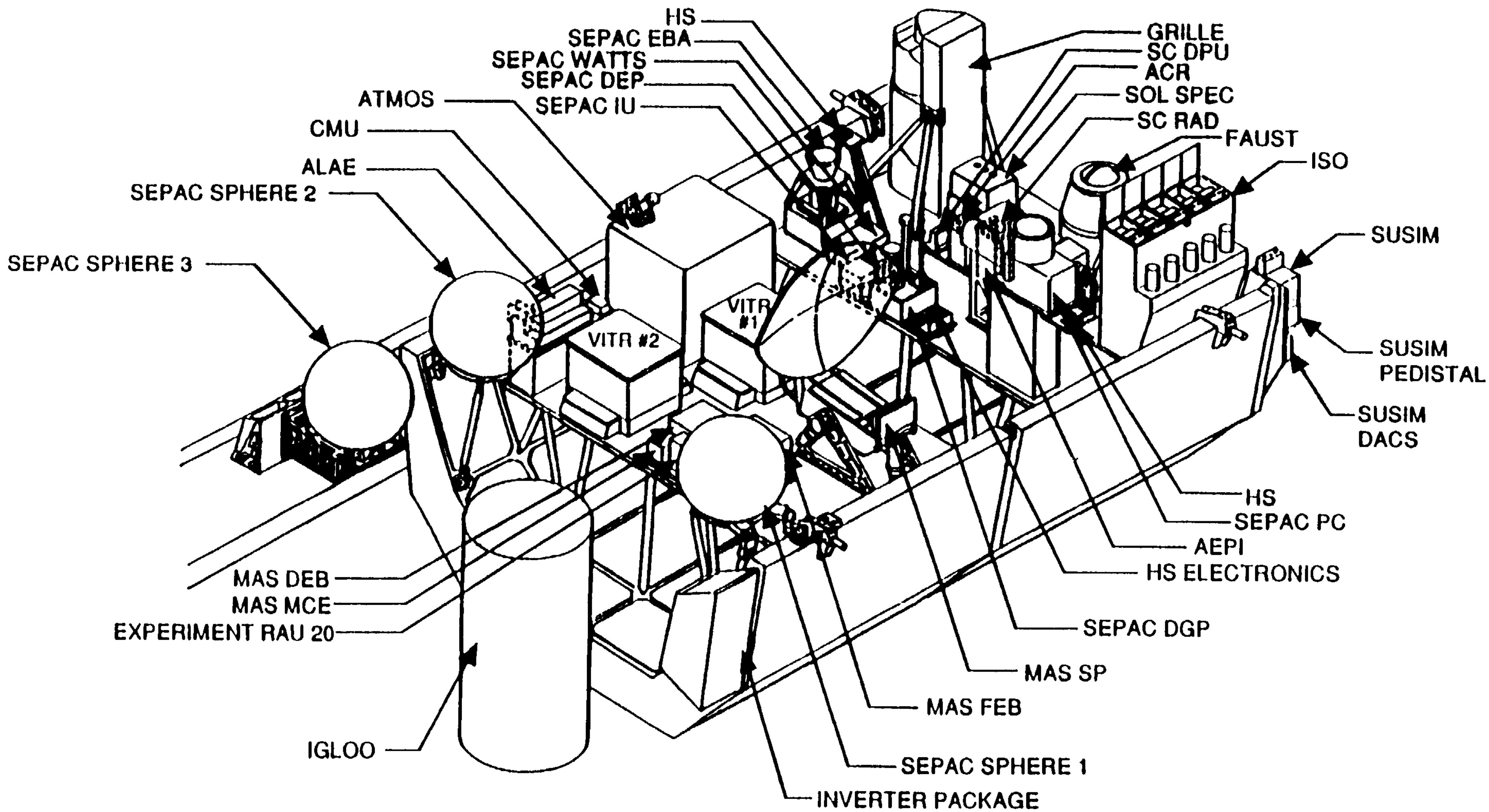
NASA

OFFICE OF SPACE SCIENCE AND APPLICATIONS

Flight Systems Division

OSSA

ATLAS - 1

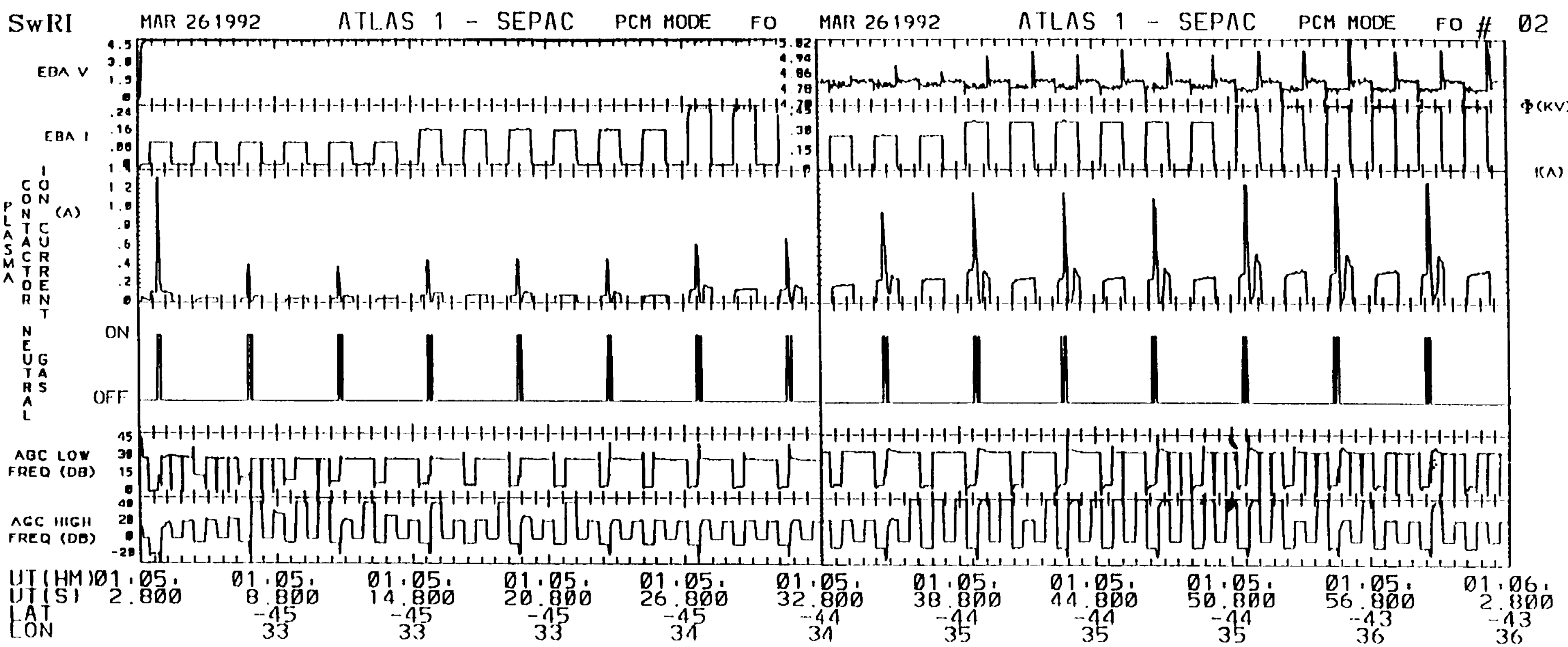


NRC

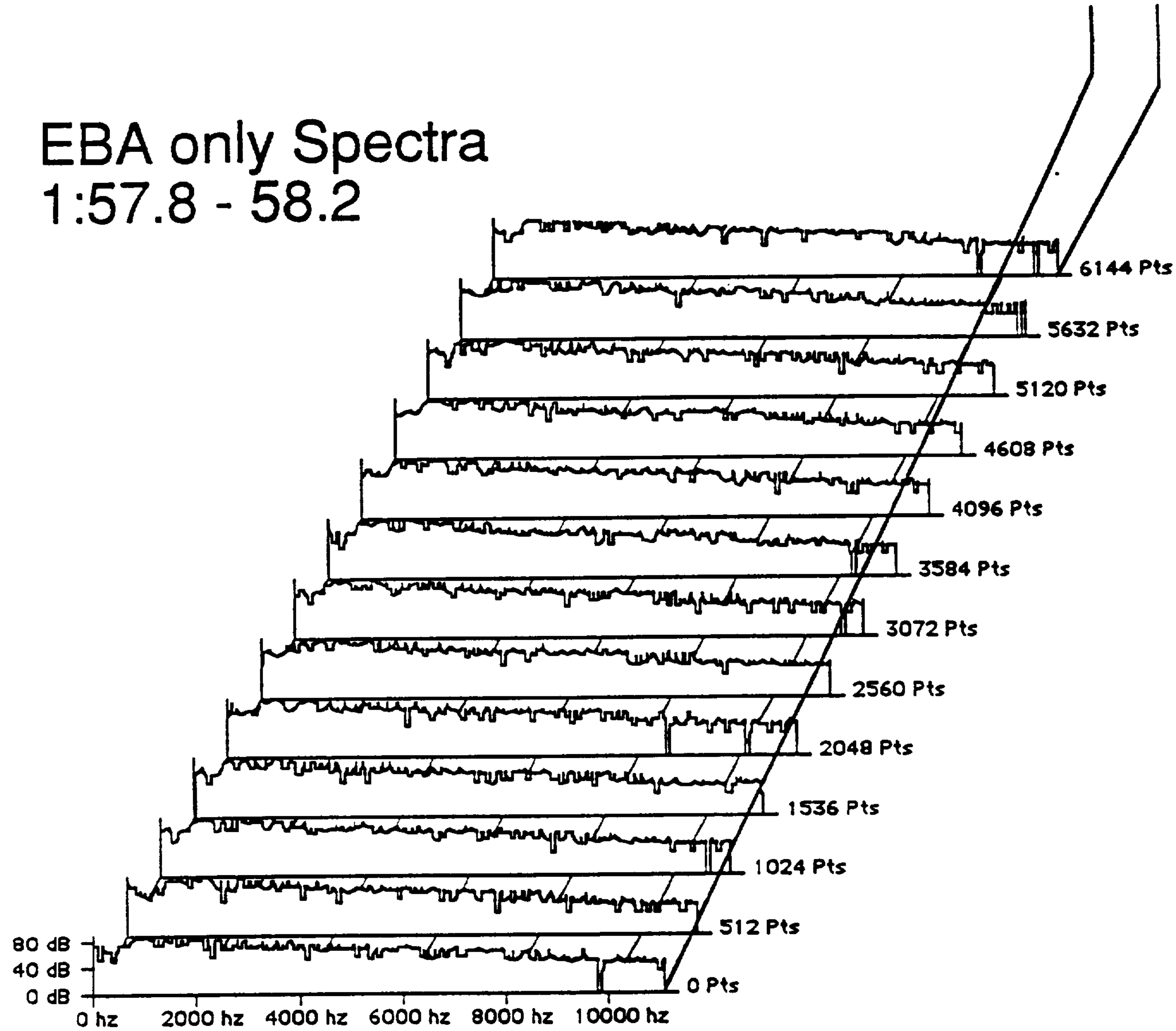
SEPAC

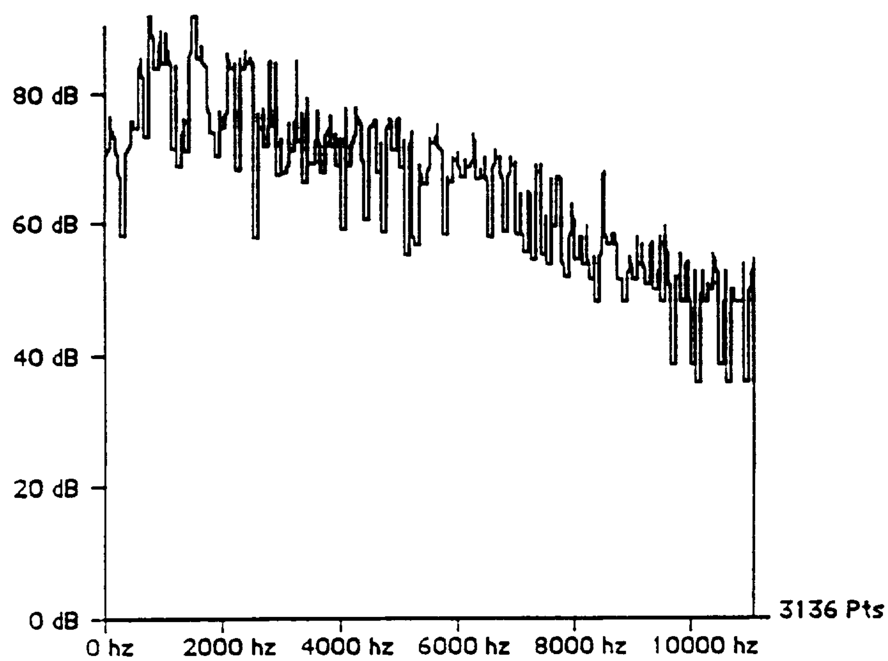
Scientific Objectives

- Operation of Electron Beam and Plasma Generators in Space
  - Vehicle Charging
  - Beam Plasma Interactions
- Beam Atmosphere Interactions
  - Artificial Aurora
  - Equatorial Aerochemistry
- Beam Magnetosphere Interactions
  - Electron Echo
  - Parallel Electric Fields
- Virtual Antennas
- Coherent Radar Targets (Picket Fence)
- Critical Velocity Ionization

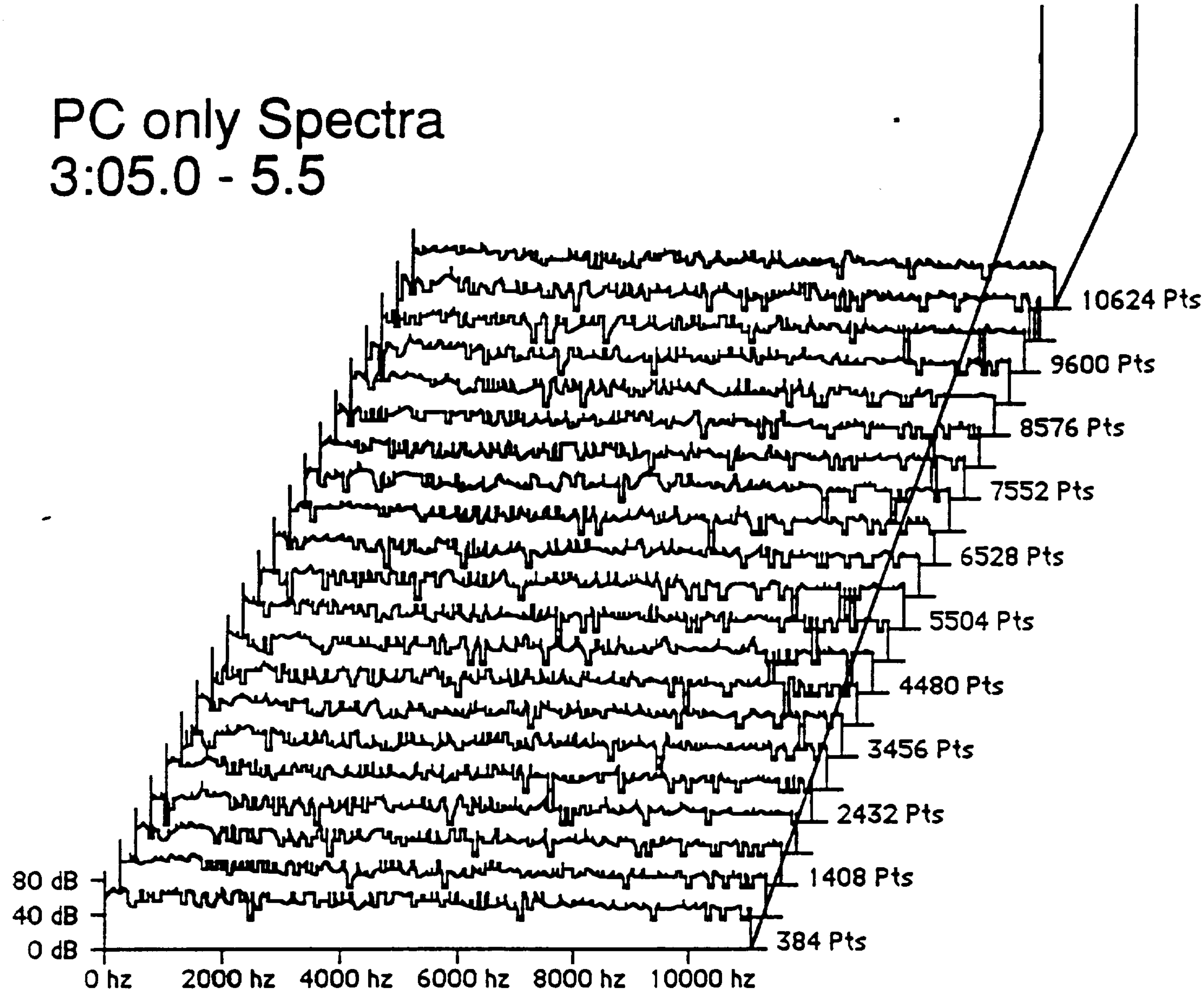

SwRI
MAR 261992 ATLAS 1 - SEPAC PCM MODE FO
MAR 261992 ATLAS 1 - SEPAC PCM MODE FO # 02
EBA V
EBA I
PLASMA CONTACTOR ION CURRENT (A)
NEUTRAL GAS
ON
OFF
AGC LOW FREQ (DB)
AGC HIGH FREQ (DB)
Φ(KV)
I(A)
UT(HM) 01:05: 01:05: 01:05: 01:05: 01:05: 01:05: 01:05: 01:05: 01:05: 01:05: 01:06:
UT(S) 2.800 8.800 14.800 20.800 26.800 32.800 38.800 44.800 50.800 56.800 2.800
LAT -45 -45 -45 -45 -44 -44 -44 -44 -43 -43
LON 33 33 33 34 34 35 35 35 36 36

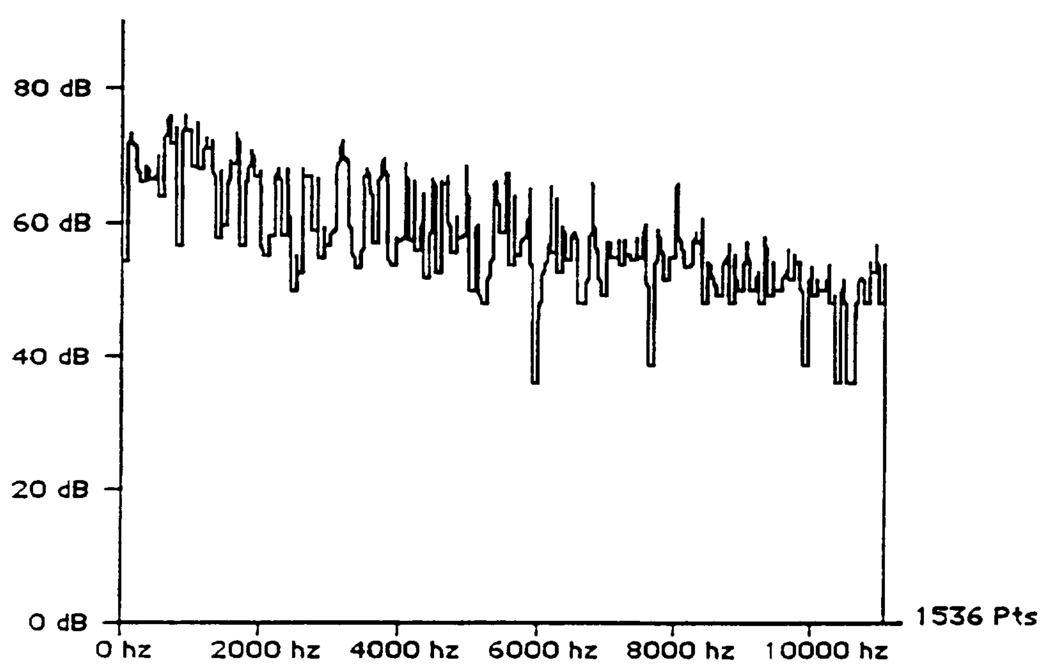
EBA only Spectra
1:57.8 - 58.2



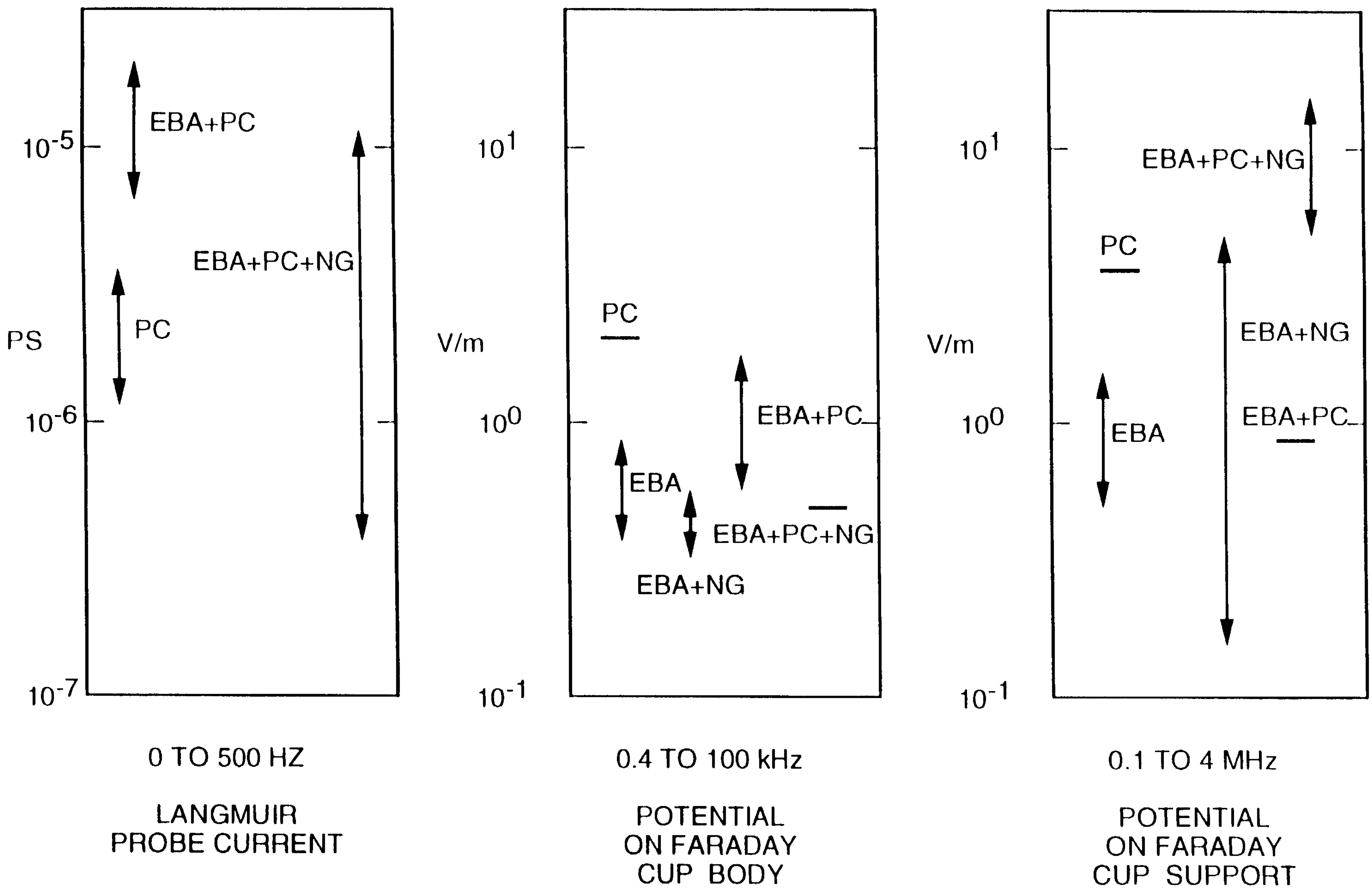


PC only Spectra
3:05.0 - 5.5





ATLAS -1 SEPAC
SUMMARY OF PLASMA WAVE AMPLITUDES
INTEGRATED OVER FREQUENCY



VA - SUMMARY

Harmonic rich pulsed beams produce harmonic rich waves

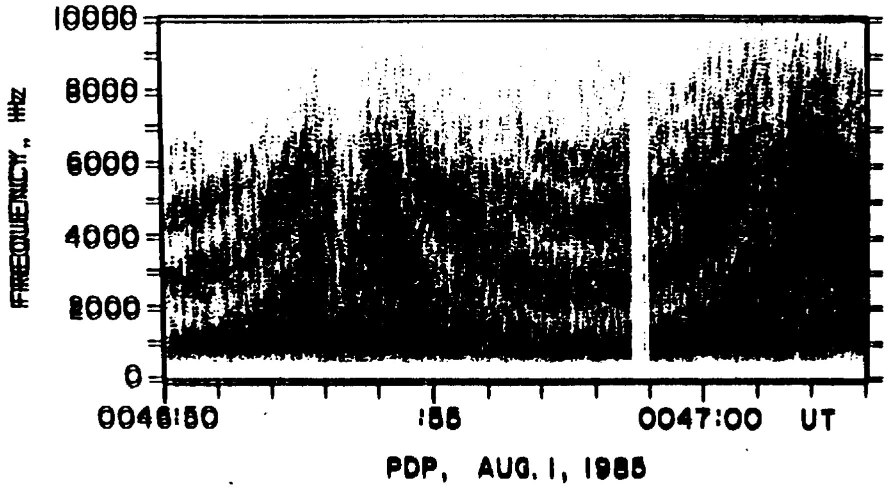
Waves detected to ~ 1 km

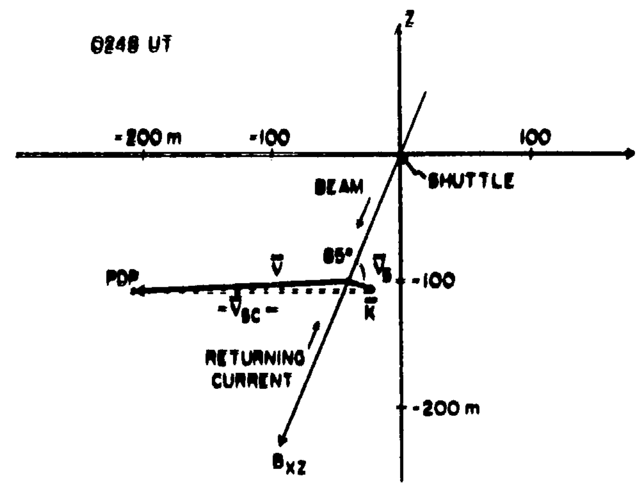
Theories have not predicted wave properties well

- Radiating current is difficult to model
- Beam particles may effect dispersion assumptions

ELECTRON BEAM RETURN CURRENT

from Feng, Gurnett and Cairns, JGR, 1992

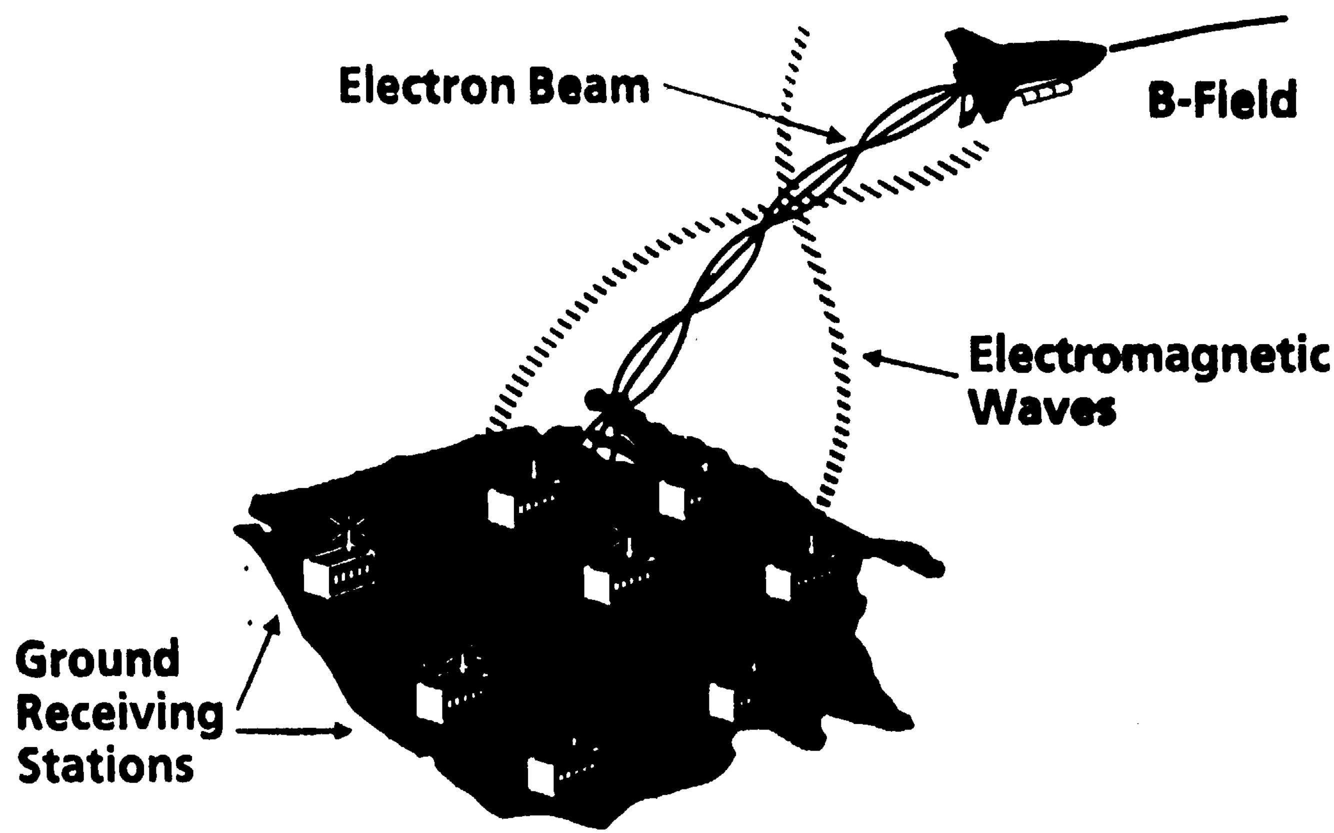




Analysis of PDP wave data generated by FPEG on SL 2

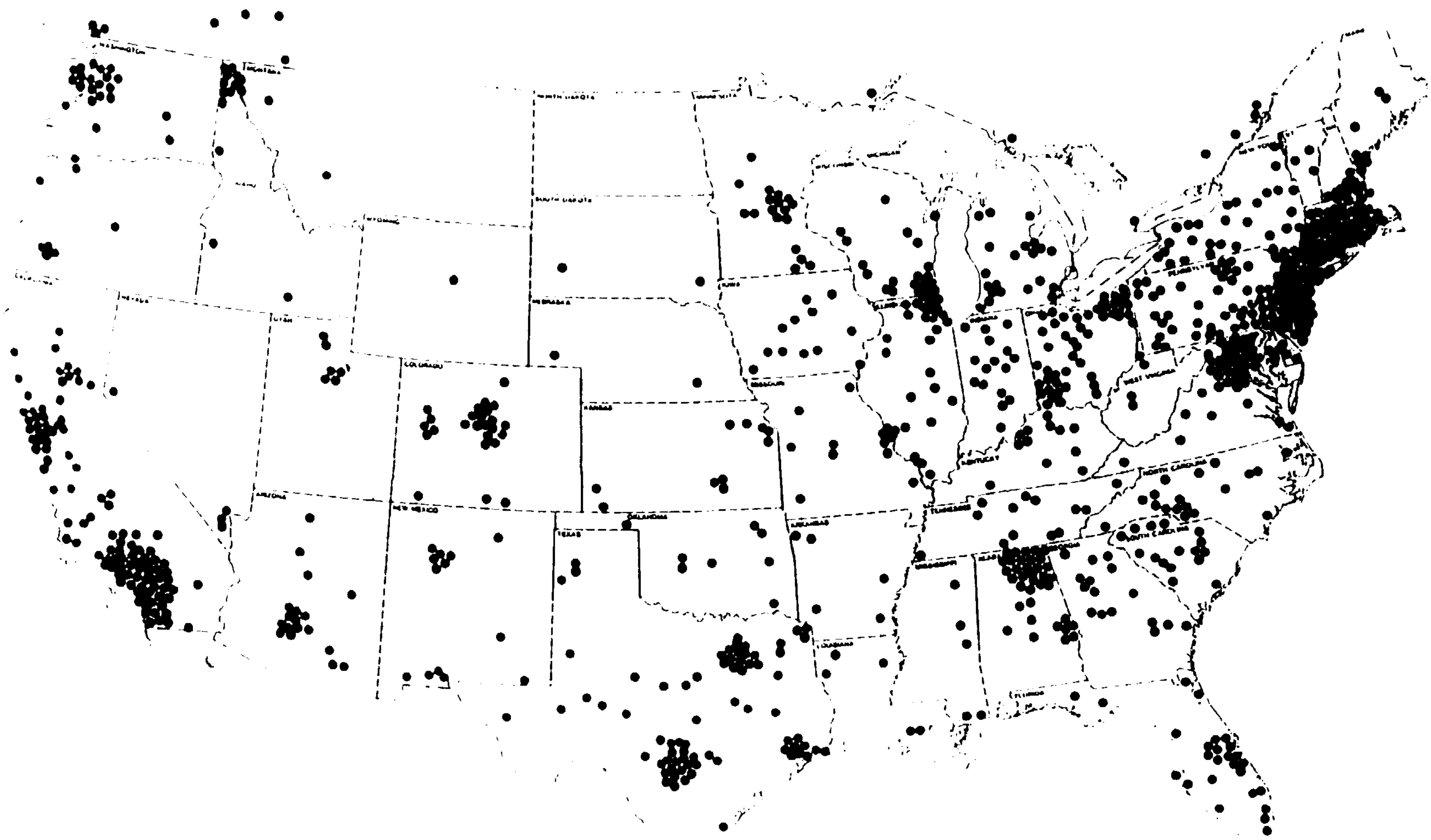
- Interference pattern in spectrograms
- Ion acoustic waves from beam return current
- Return current along beam current
- Within about 20 meters of electron beam

INSPIRE CONCEPT

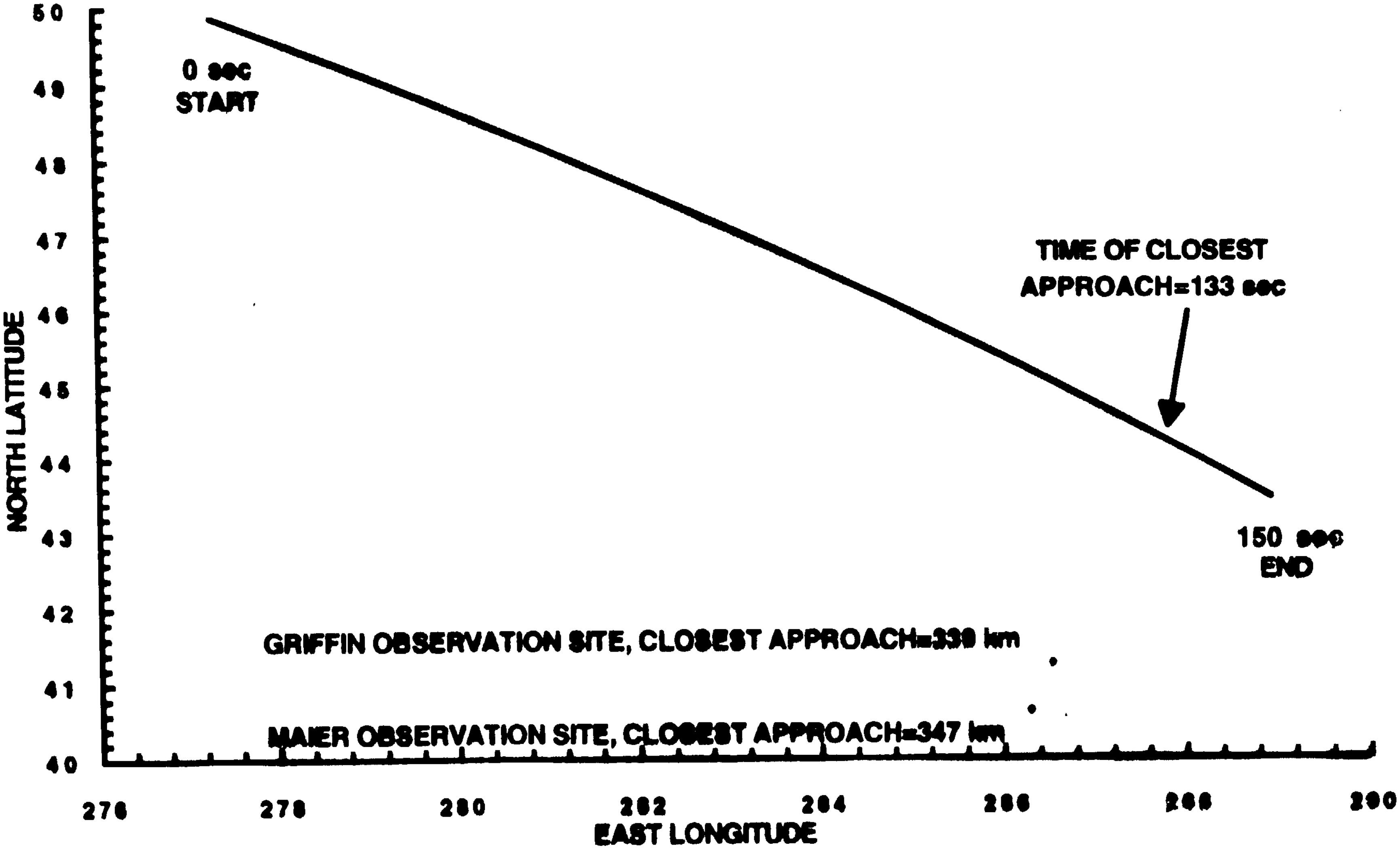


OSS-17714
1/28/92

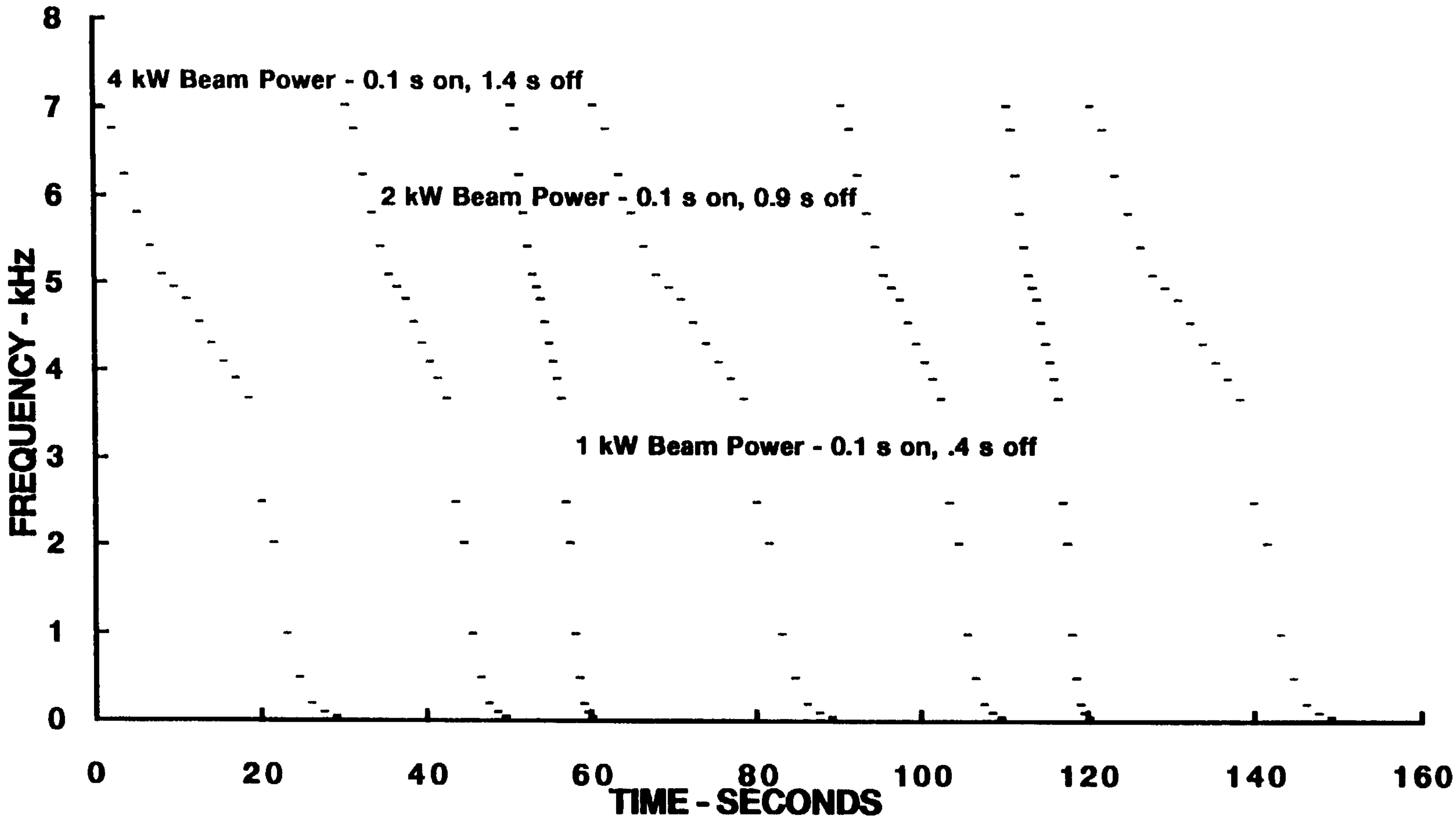
1000 OBSERVING SITES FOR INSPIRE



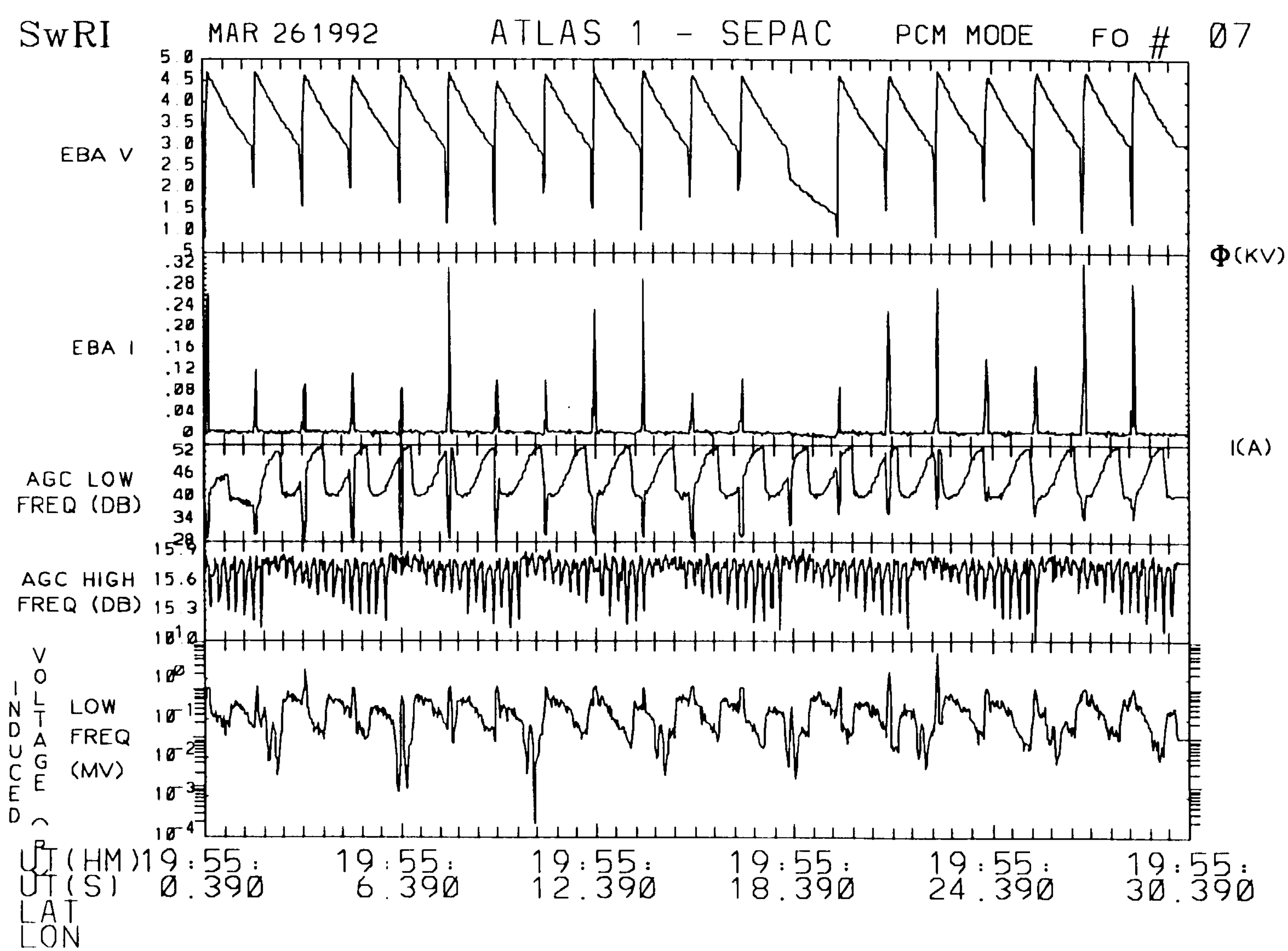
OBSERVATION SITES FOR FO 7-2



ATLAS 1 SEPAC FUNCTIONAL OBJECTIVE 7-2 FORMAT

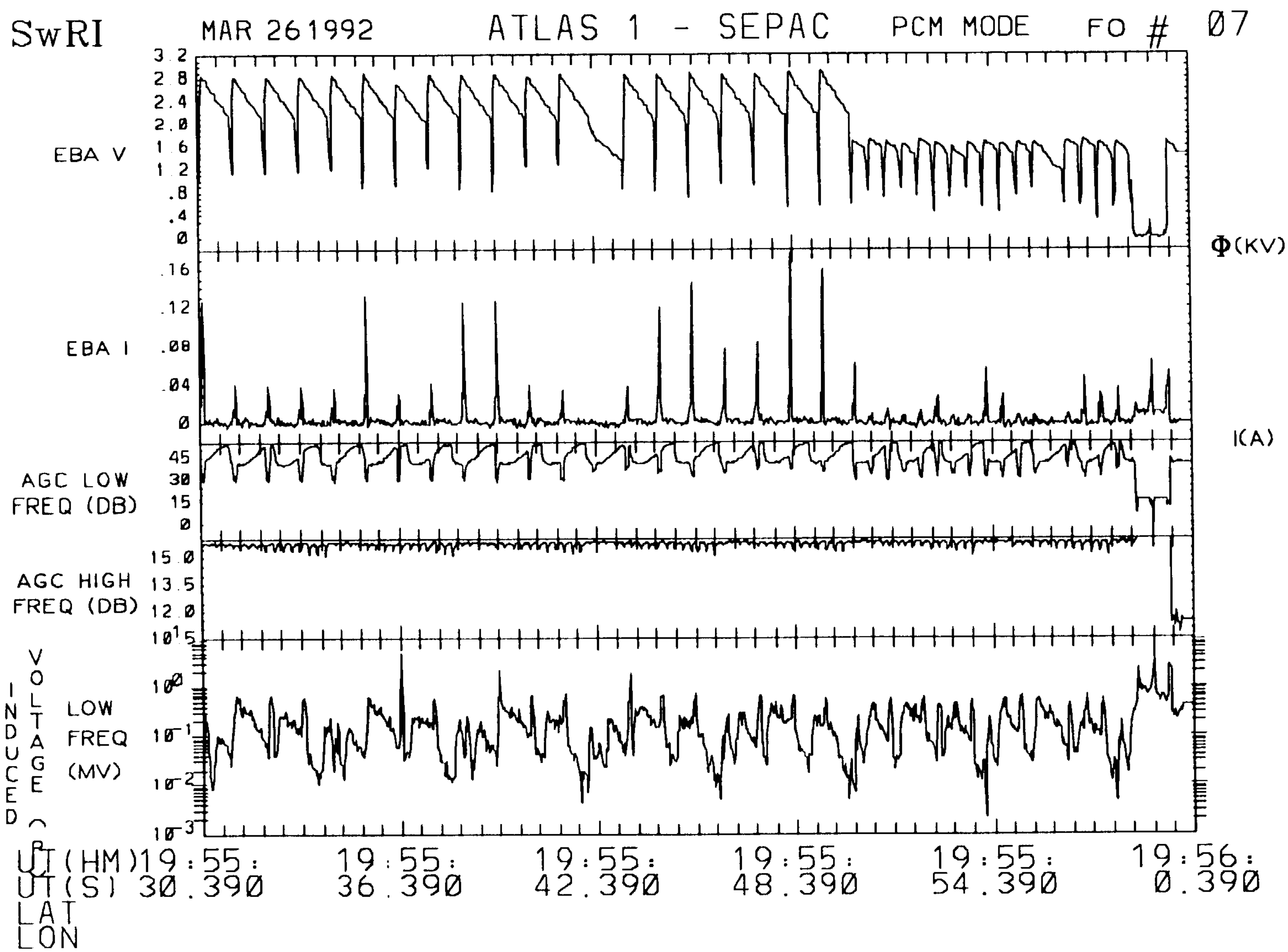


READY>

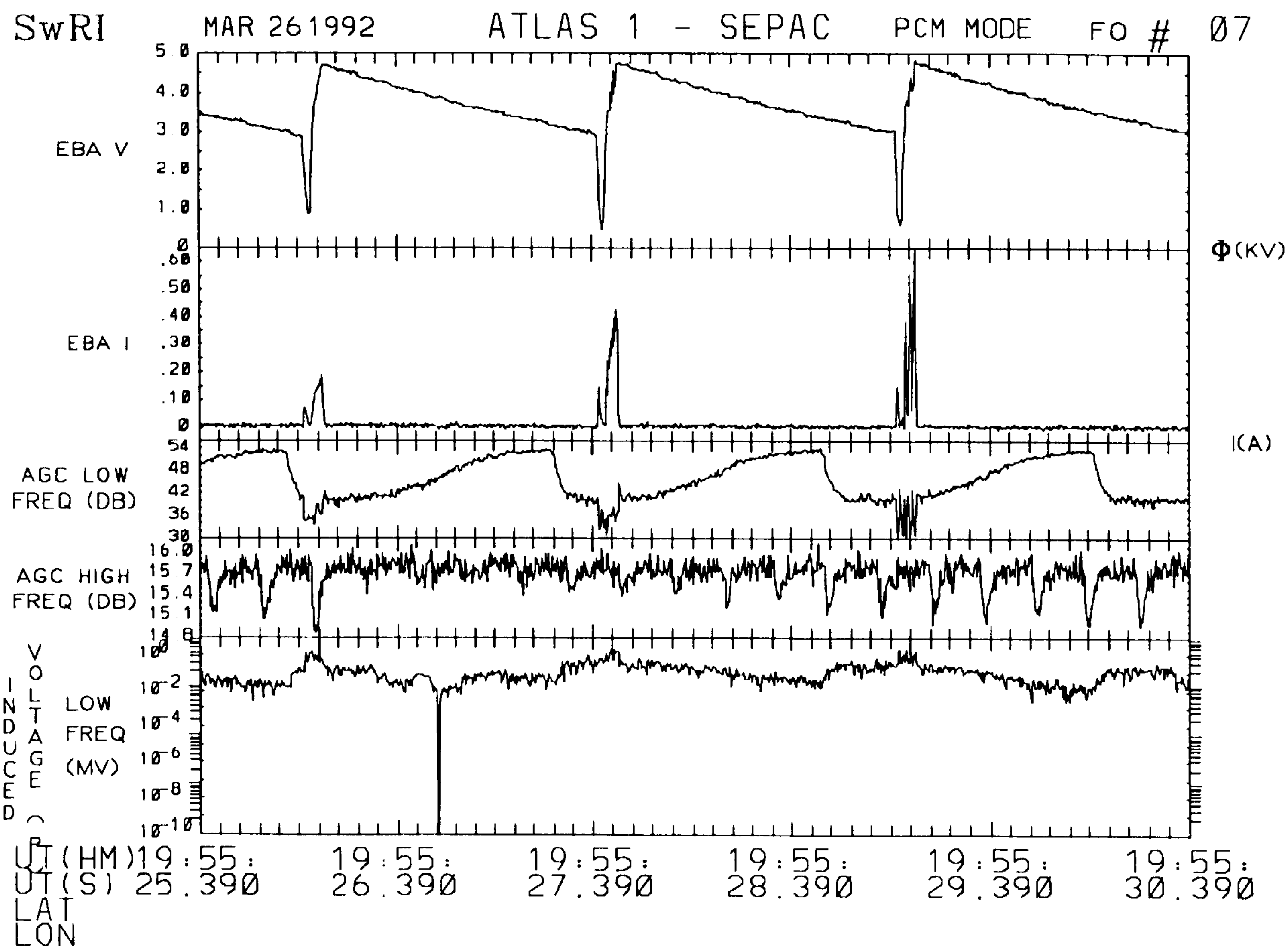


SwRI
MAR 26 1992
ATLAS 1 - SEPAC
PCM MODE
FO # 07
EBA V
Φ(KV)
EBA I
I(A)
AGC LOW FREQ (DB)
AGC HIGH FREQ (DB)
INDUCED VOLTAGE
LOW FREQ (MV)
UT(HM) 19:55: 19:55: 19:55: 19:55: 19:55: 19:55:
UT(S) 0.390 6.390 12.390 18.390 24.390 30.390
LAT
LON

READY>

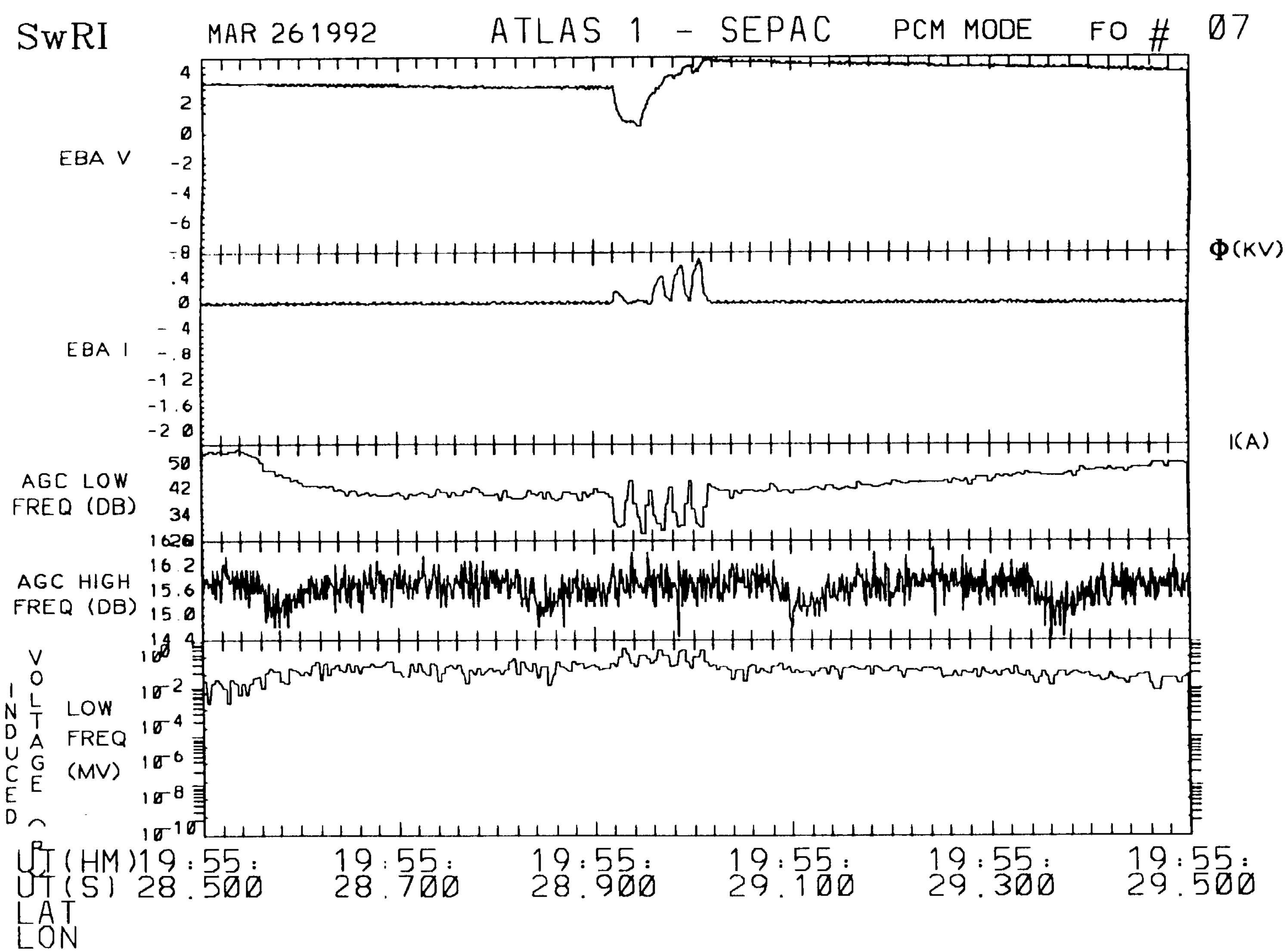

SwRI
MAR 26 1992
ATLAS 1 - SEPAC
PCM MODE
FO # 07
EBA V
3.2
2.8
2.4
2.0
1.6
1.2
.8
.4
0
Φ(KV)
EBA I
.16
.12
.08
.04
0
I(A)
AGC LOW FREQ (DB)
45
30
15
0
AGC HIGH FREQ (DB)
15.0
13.5
12.0
10.5
INDUCED VOLTAGE
LOW FREQ (MV)
10^0
10^-1
10^-2
10^-3
UT(HM) 19:55: 19:55: 19:55: 19:55: 19:55: 19:56:
UT(S) 30.390 36.390 42.390 48.390 54.390 0.390
LAT
LON

READY>



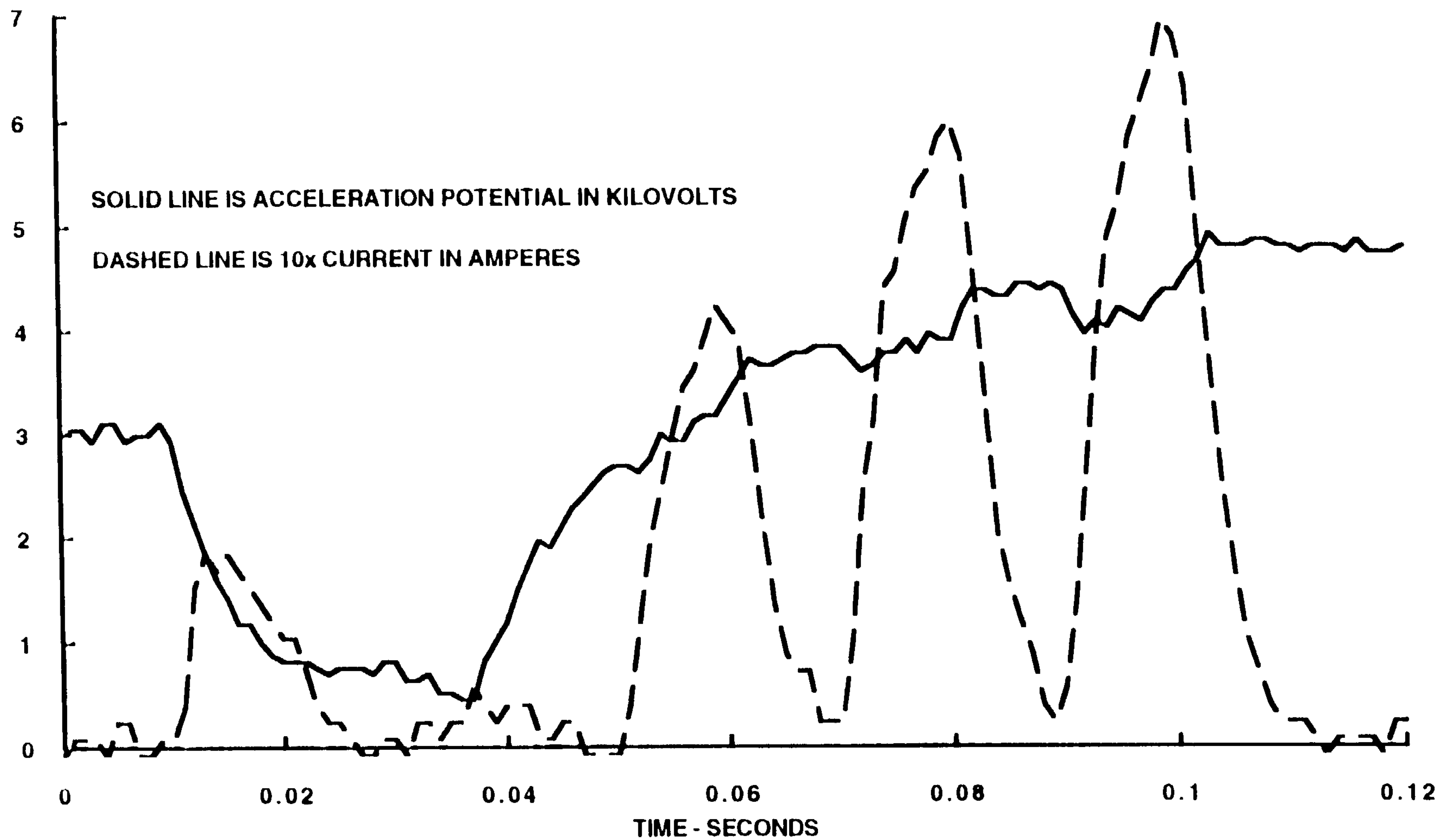
SwRI
MAR 26 1992
ATLAS 1 - SEPAC
PCM MODE
FO # 07
EBA V
5.0
4.0
3.0
2.0
1.0
0
Φ(KV)
EBA I
.60
.50
.40
.30
.20
.10
0
I(A)
AGC LOW FREQ (DB)
54
48
42
36
30
AGC HIGH FREQ (DB)
16.0
15.7
15.4
15.1
14.8
INDUCED VOLTAGE
LOW FREQ (MV)
10^0
10^-2
10^-4
10^-6
10^-8
10^-10
UT(HM) 19:55: 19:55: 19:55: 19:55: 19:55: 19:55:
UT(S) 25.390 26.390 27.390 28.390 29.390 30.390
LAT
LON

READY>

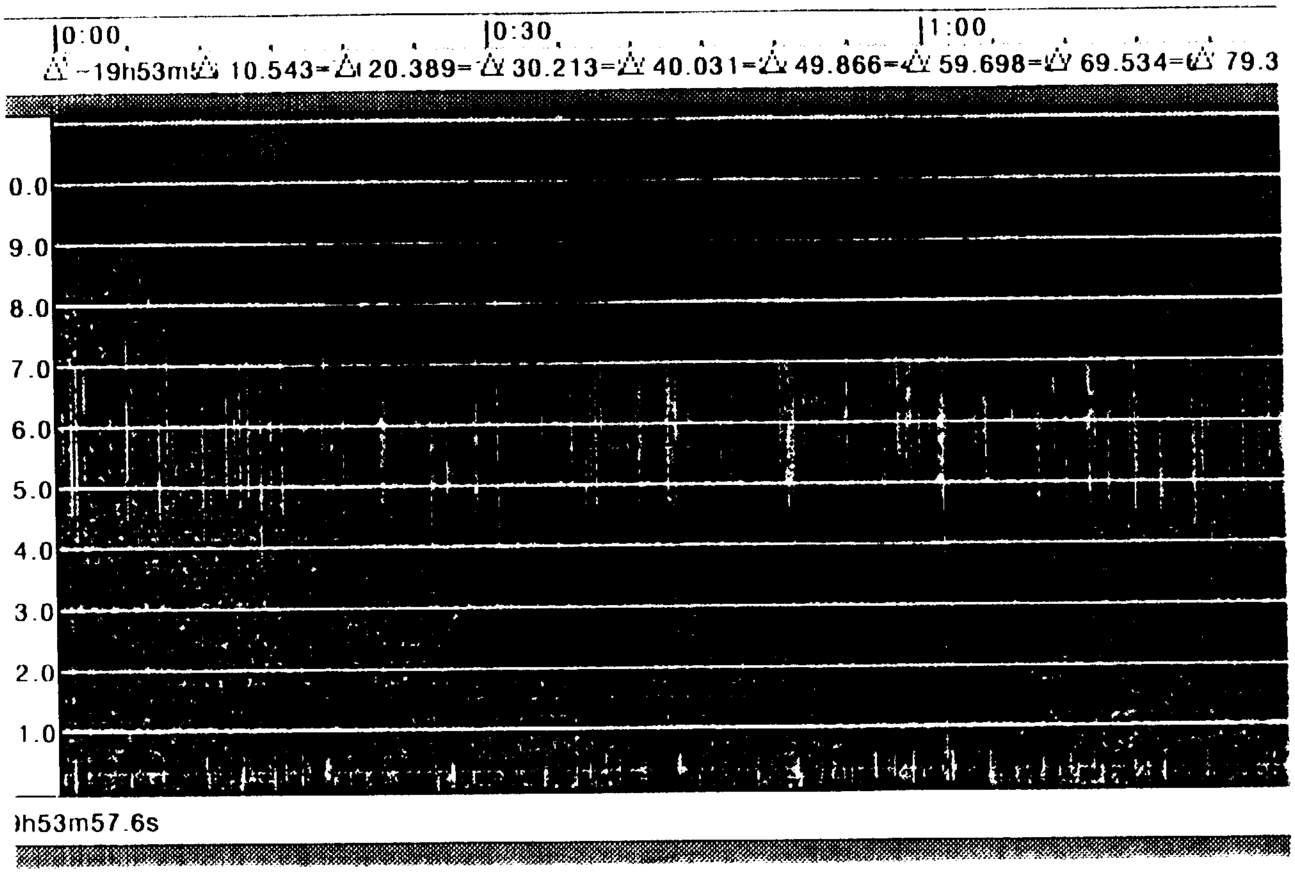


SwRI
MAR 261992
ATLAS 1 - SEPAC
PCM MODE
FO # 07
EBA V
4
2
0
-2
-4
-6
-8
Φ(KV)
.4
0
EBA I
-.4
-.8
-1.2
-1.6
-2.0
I(A)
AGC LOW FREQ (DB)
50
42
34
AGC HIGH FREQ (DB)
16.2
15.6
15.0
INDUCED VOLTAGE LOW FREQ (MV)
10^0
10^-2
10^-4
10^-6
10^-8
10^-10
UT(HM) 19:55: 19:55: 19:55: 19:55: 19:55: 19:55:
UT(S) 28.500 28.700 28.900 29.100 29.300 29.500
LAT
LON

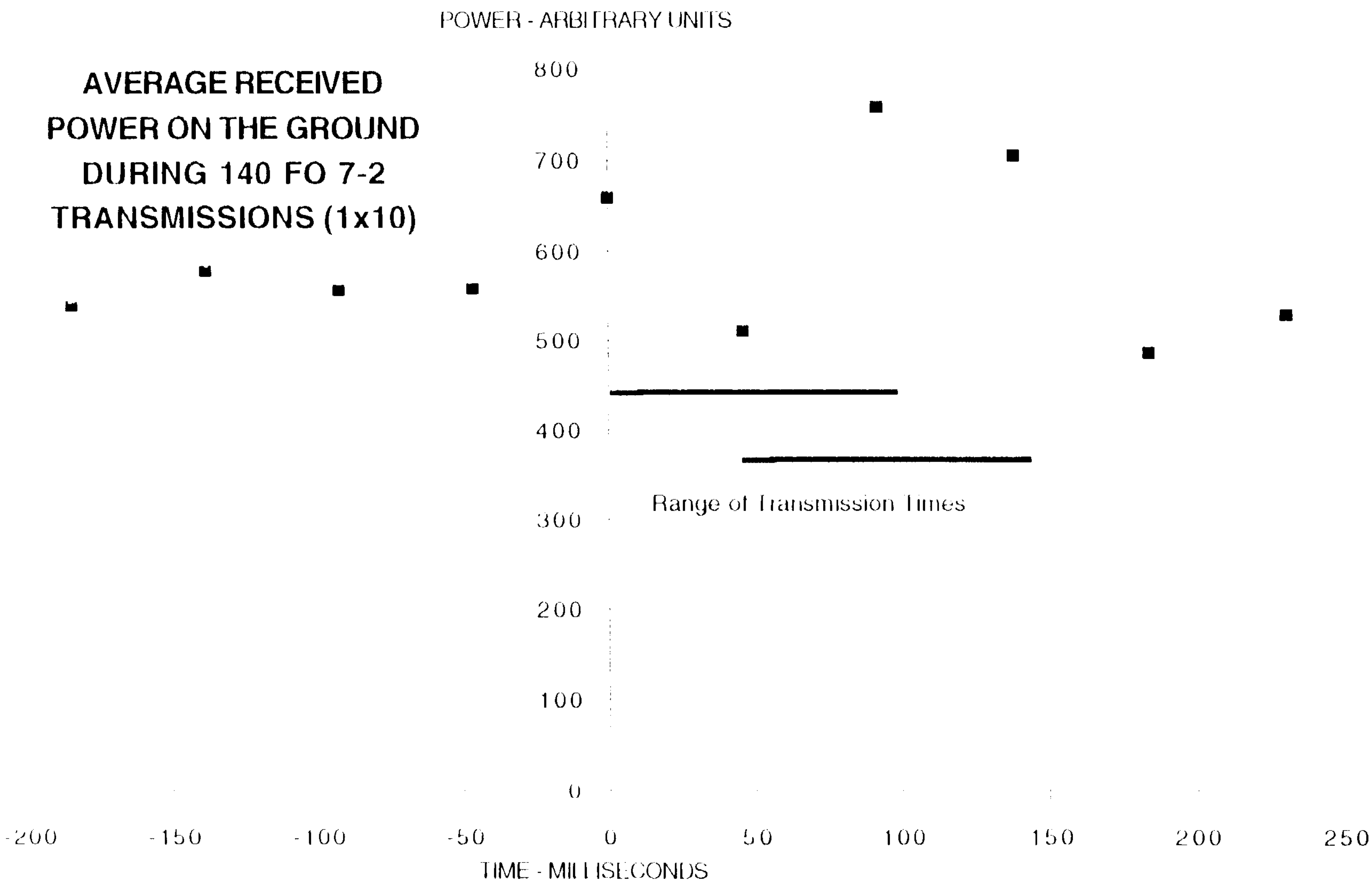
FO 7-2 50 Hz TRANSMISSION

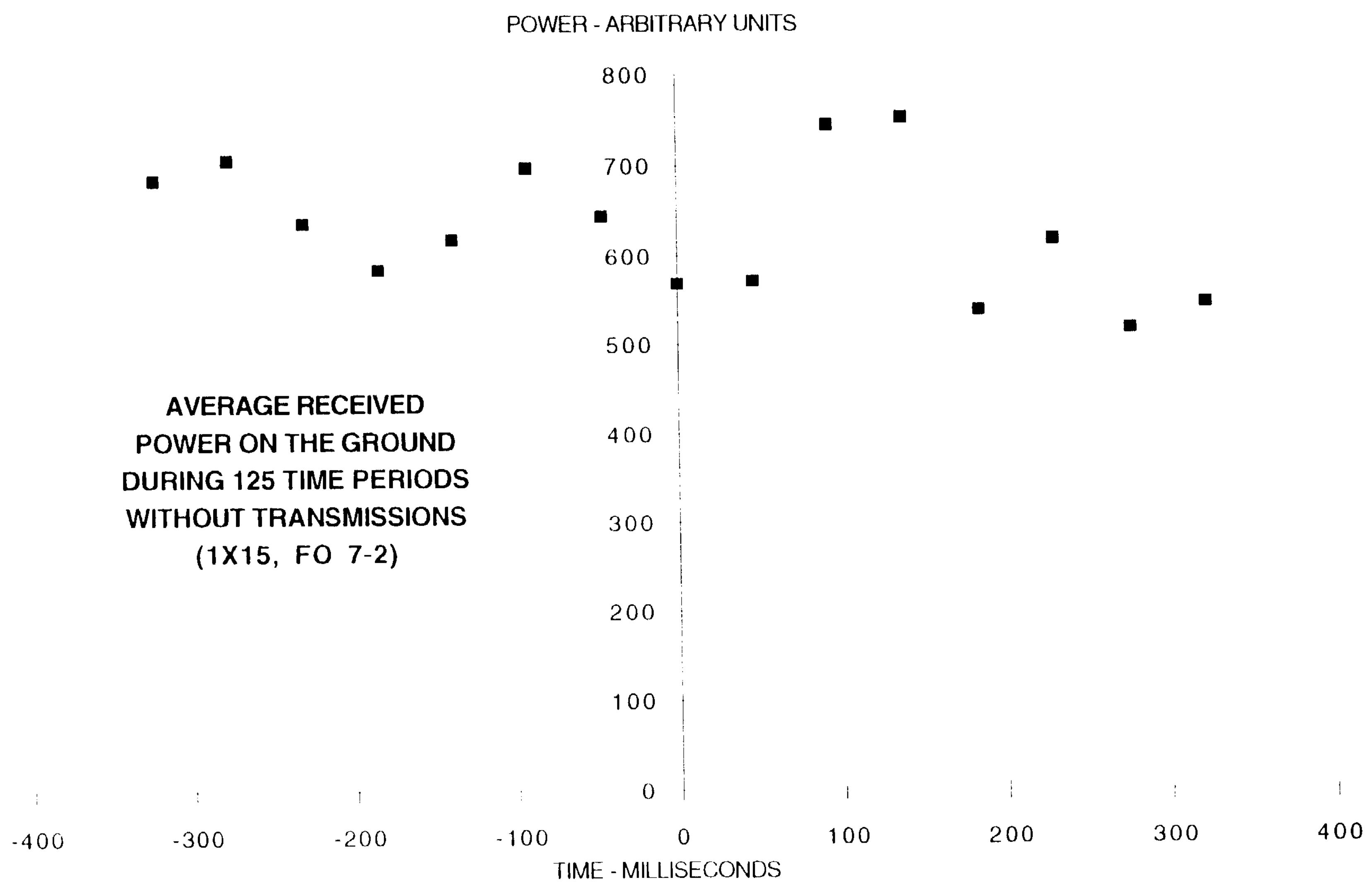


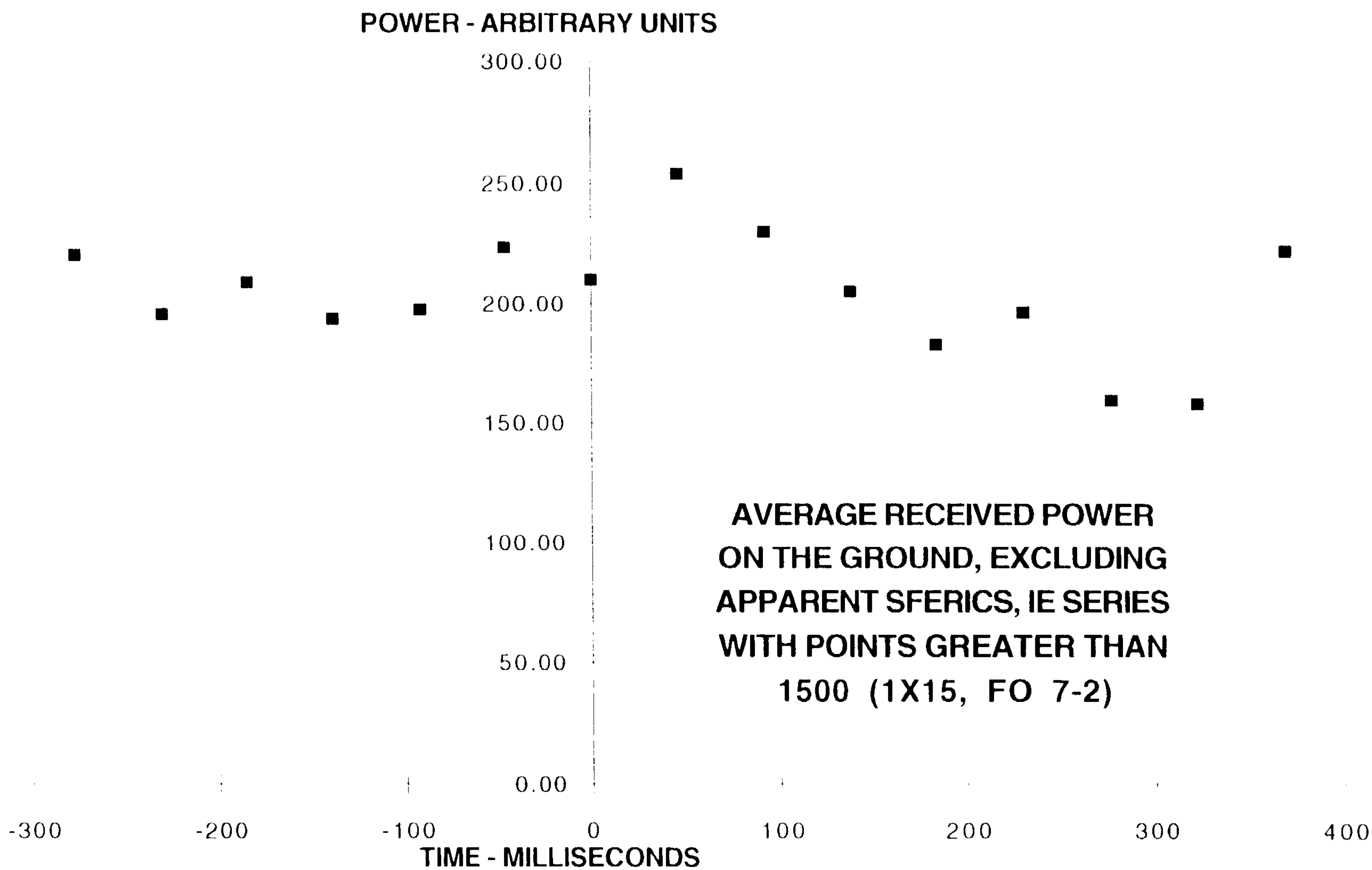
6/14/93.griffin.2.6min: page 1 of 1



AVERAGE RECEIVED POWER ON THE GROUND DURING 140 FO 7-2 TRANSMISSIONS (1x10)




POWER - ARBITRARY UNITS
800
700
600
500
400
300
200
100
0
-400
-300
-200
-100
0
100
200
300
400
TIME - MILLISECONDS
AVERAGE RECEIVED
POWER ON THE GROUND
DURING 125 TIME PERIODS
WITHOUT TRANSMISSIONS
(1X15, FO 7-2)


POWER - ARBITRARY UNITS
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-300
-200
-100
0
100
200
300
400
TIME - MILLISECONDS
AVERAGE RECEIVED POWER
ON THE GROUND, EXCLUDING
APPARENT SFERICS, IE SERIES
WITH POINTS GREATER THAN
1500 (1X15, FO 7-2)

SELECTION OF POINTS FROM THE FREQUENCY - TIME PLANE

FREQUENCY - HERTZ

NUMBER OF DATA POINTS FROM BEGINNING OF SELECTION	4498	4520	4542	4563	4585	4607	4629	4650	4672	4694	4715	4737	4759	4781	4802
0	136	68	32	344	190	25	243	217	68	127	6	220	348	136	2
1024	158	378	335	890	585	690	1020	1522	480	693	1062	801	6002	1400	2664
2048	1684	140	1651	1521	578	378	186	215	228	985	1773	235	2076	2709	2368
3072	181	10	388	514	666	444	98	347	1188	1452	613	145	21	729	14
4096	1056	378	61	45	49	16	189	42	77	45	222	1513	1045	6	171
5120	1344	812	511	565	927	256	482	1450	1033	421	1625	1657	3756	1551	2155
6144	1052	189	84	190	274	1009	231	778	193	212	1465	2328	308	384	416
7168	235	726	181	36	120	577	173	**438**	45	47	106	890	265	167	189
8192	1200	970	312	238	75	642	5[illegible]	105	522	478	648	1862	697	68	242
9216	168	107	36	761	1488	1082	1717	447	599	1072	27	612	134	714	1824
10240	265	912	410	116	23	370	95	156	270	355	173	84	1113	1147	245
11264	52	46	92	180	255	57	18	18	299	289	397	529	480	1410	149
12288	60	452	78	95	22	194	240	82	37	169	143	484	1664	202	168
13312	363	787	49	98	60	106	1[illegible]	7	52	49	32	225	1219	118	46
14336	189	1257	1040	108	296	1568	5401	5147	1181	1337	526	1080	1878	2954	1251

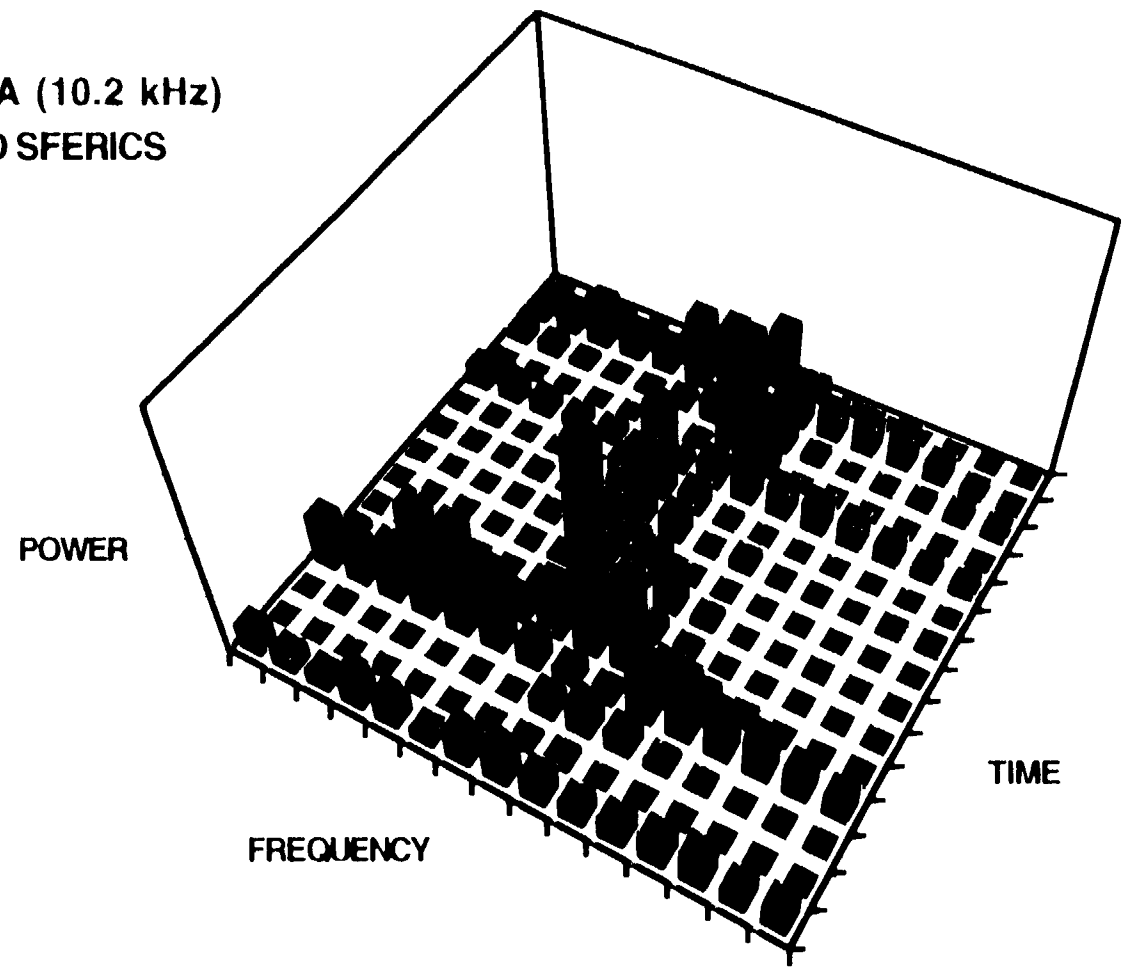
15x15

TARGET POINT

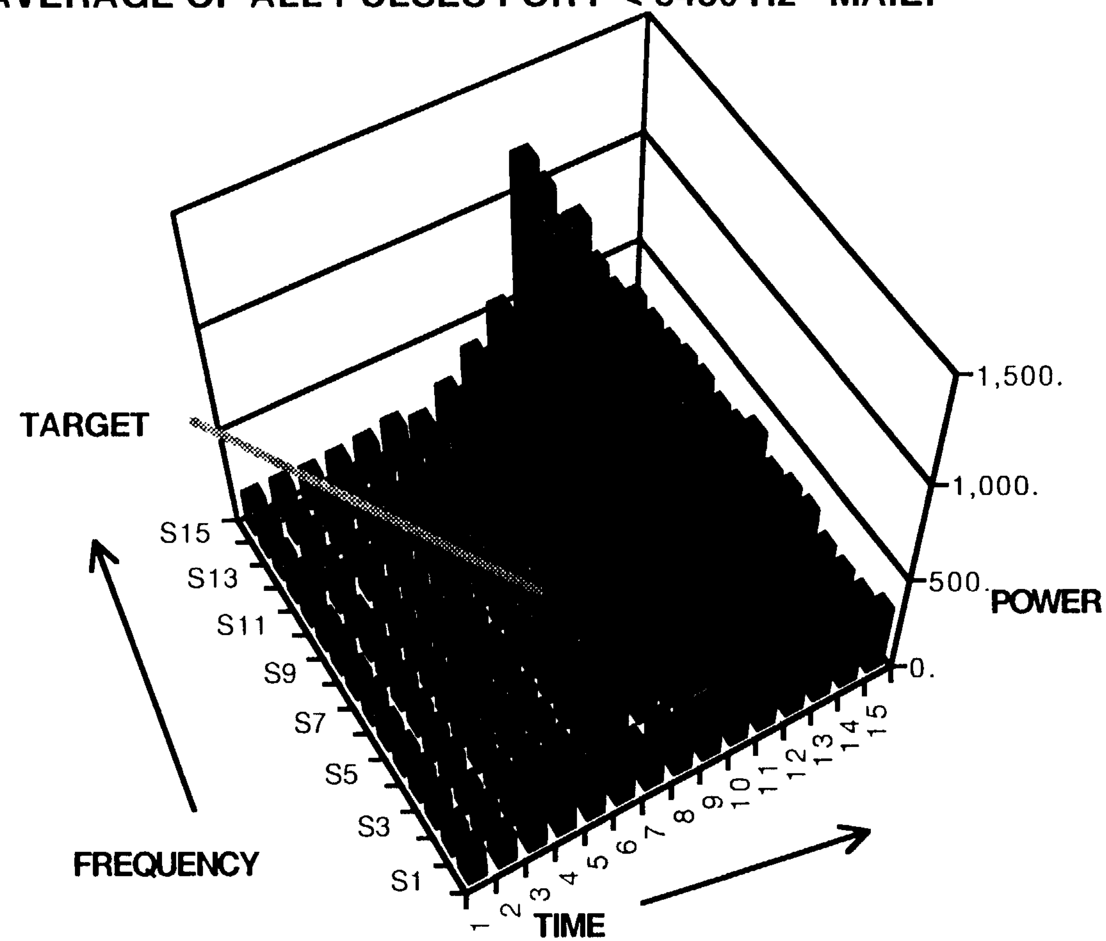
1x10

1x15

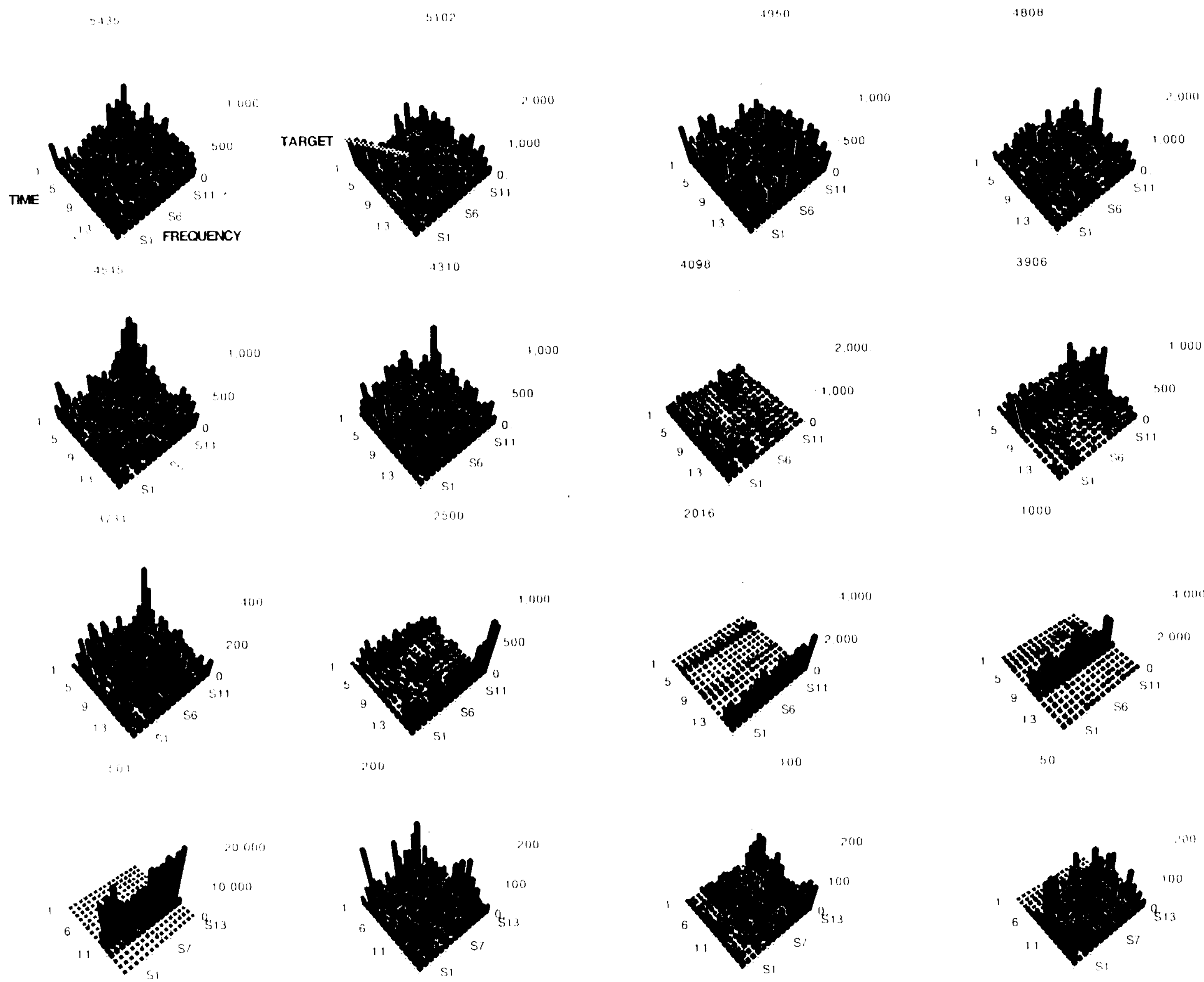
OMEGA (10.2 kHz)
AND SFERICS



AVERAGE OF ALL PULSES FOR F < 5450 Hz - MAIEF



ALL PULSES - MAIER



NRC

SEPAC

CONCLUSION

- No evidence has yet been found of detection on the ground of SEPAC virtual antenna waves.

THE EMISSIONS FROM PULSED BEAMS (VIRTUAL ANTENNAS) EMITTED BY SEPAC ON ATLAS 1

By

W. Taylor
Nichols Research Corporation

December 6-10, 1993

American Geophysical Union Meeting
San Francisco, CA

The Emissions from Pulsed Beams (Virtual Antennas) Emitted by SEPAC on ATLAS 1

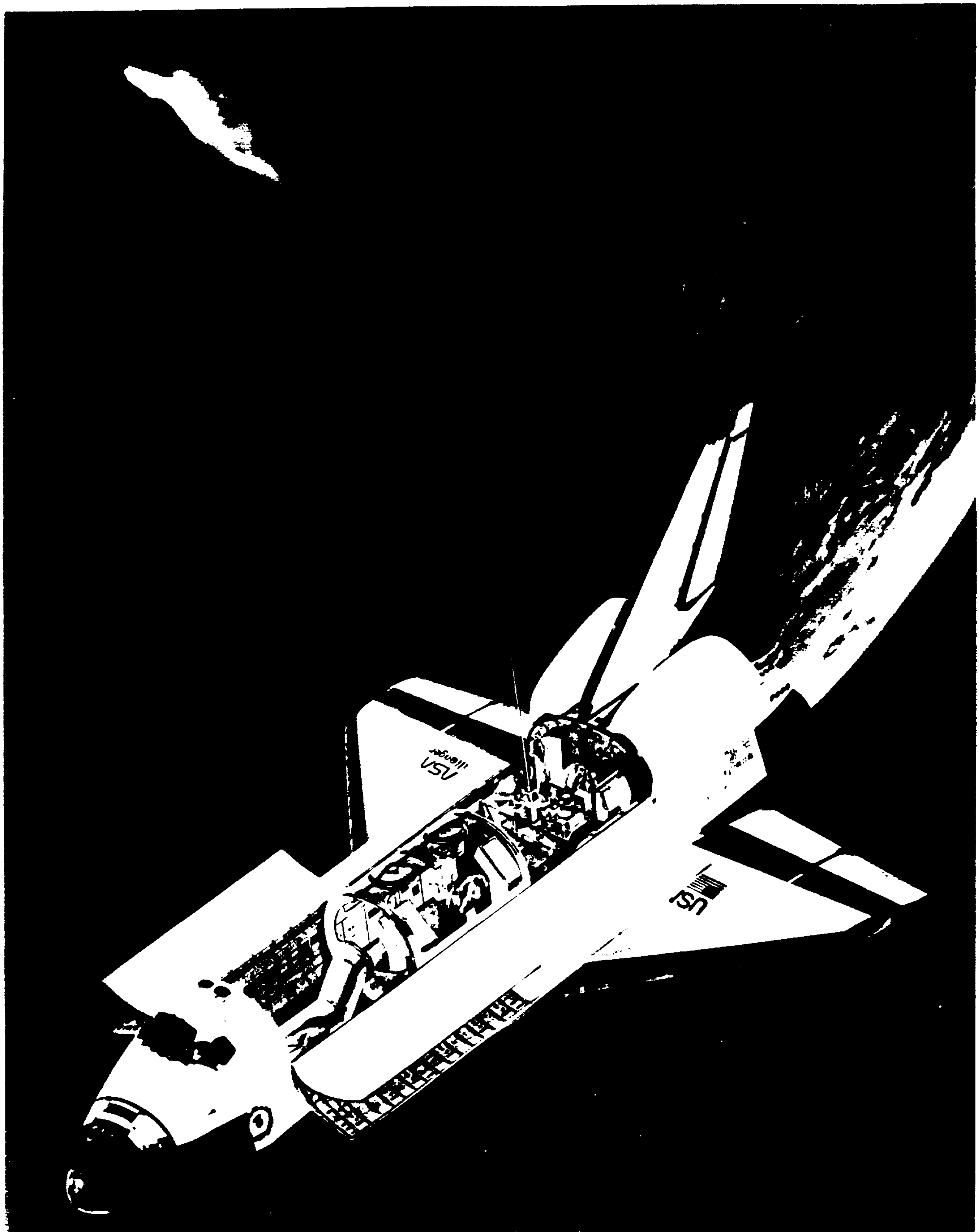
By William W. L. Taylor
Nichols Research Corporation
Arlington, VA 22209

Abstract

EPAC (Space Experiments with Particle ACcelerators) flew on the ATLAS-1 (ATmospheric Laboratory for pplications and Science) Shuttle/Spacelab mission in March and April, 1992. SEPAC equipment included an ectron accelerator, a plasma contactor for charge neutralization, and diagnostics. The electron accelerator ejected eams of electrons at energies up to 6.25 keV with currents up to 1.2 Amps. The diagnostics included a set of plasma ave instruments for measuring electric fields in the payload bay at frequencies from below 100 Hz to 10 MHz. A ajor objective of the SEPAC flight was to investigate the operation of virtual antennas in space.

eams pulsed at frequencies between 50 Hz and 7 kHz were emitted twice during the ATLAS 1 mission, over Japan, ith a maximum beam power of 2 kW and over the northeastern United States, with a maximum power of 4 kW. round based electric field data was examined in detail from two observers in the US, within 350 km of the ground ack of the shuttle, which was at an altitude of about 300 km. To date, conclusive evidence of ground observation of aves generated by the pulsed beam. has not been found.


ATMOS
IRRADIANCE
NASA



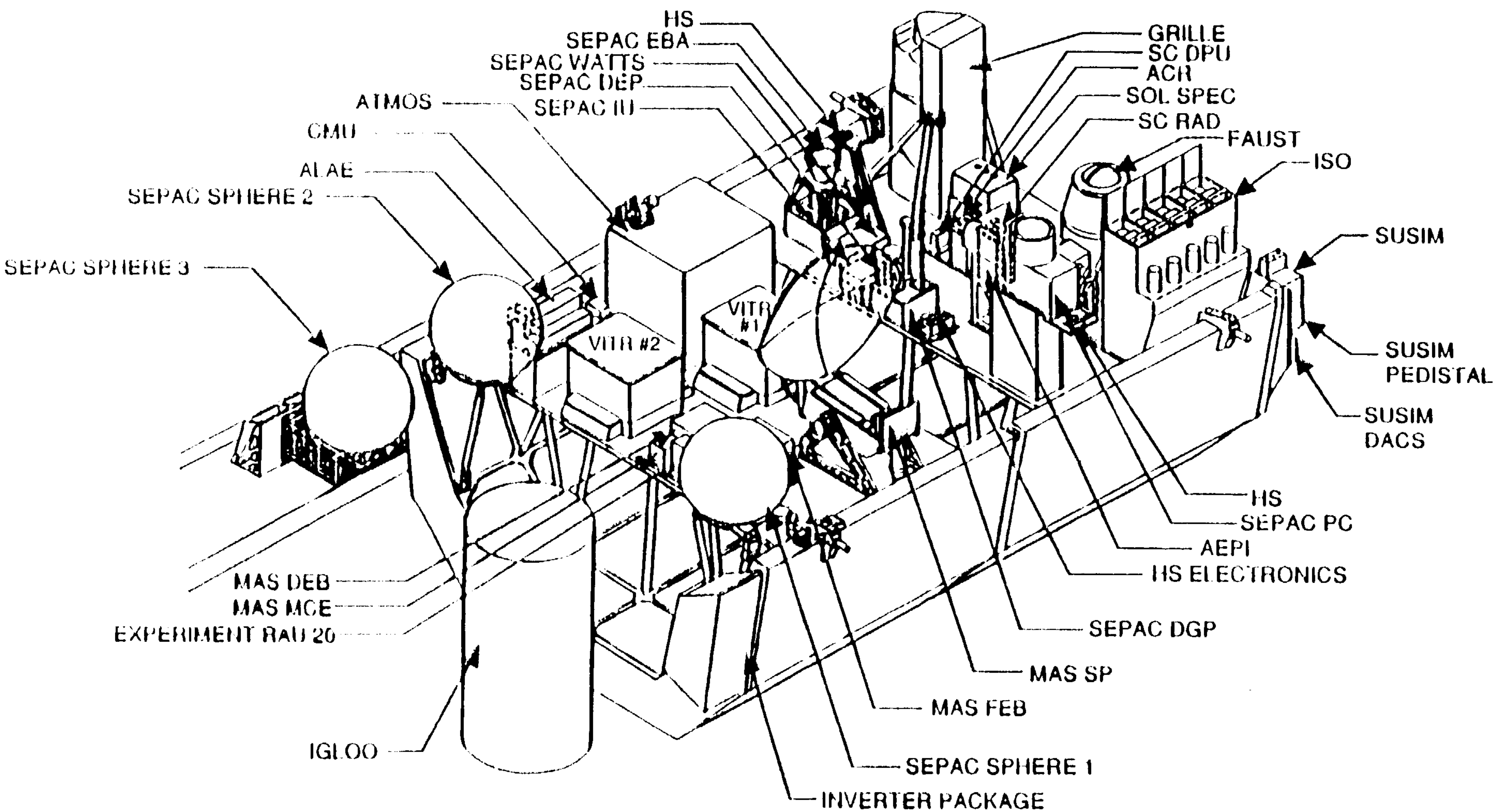
NASA

OFFICE OF SPACE SCIENCE AND APPLICATIONS

Flight Systems Division

OSSA

ATLAS - 1



NRC

SEPAC

Characteristics of SEPAC Instrumentation

- Electron Beam Accelerator
  - Maximum Beam Energy - 6.25 kV
  - Maximum Beam Current - 1.24 A
- Plasma Contactor
  - Gas - Xenon
  - Ion-Electron Production Rate - >1.6 A
- Diagnostic Instrumentation
  - Plasma Wave Detectors
  - Energetic Electron Analyzer
  - Langmuir Probe

VA - SUMMARY

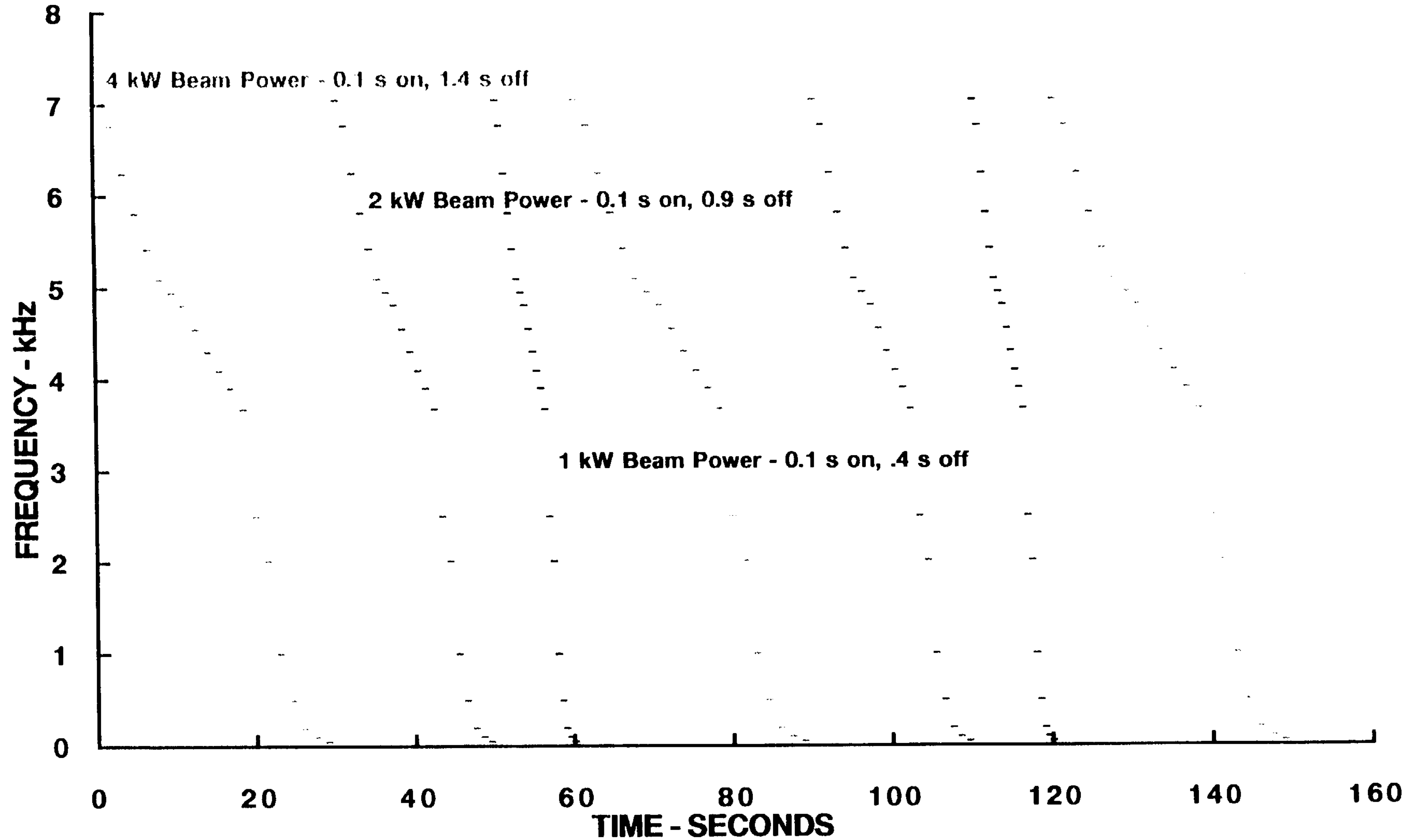
Harmonic rich pulsed beams produce harmonic rich waves

Waves detected to ~ 1 km

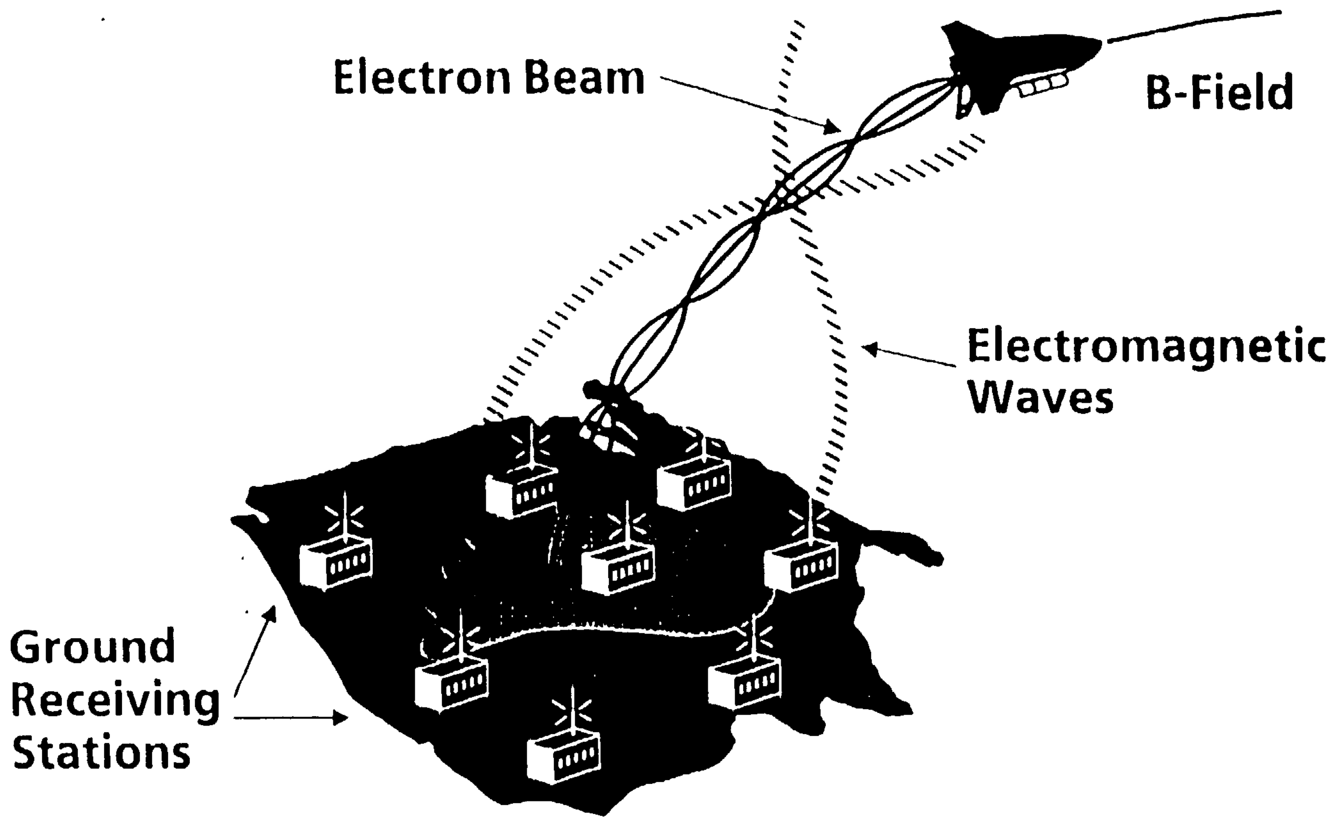
Theories have not predicted wave properties well

- Radiating current is difficult to model
- Beam particles may effect dispersion assumptions

ATLAS 1 SEPAC FUNCTIONAL OBJECTIVE 7-2 FORMAT



INSPIRE CONCEPT



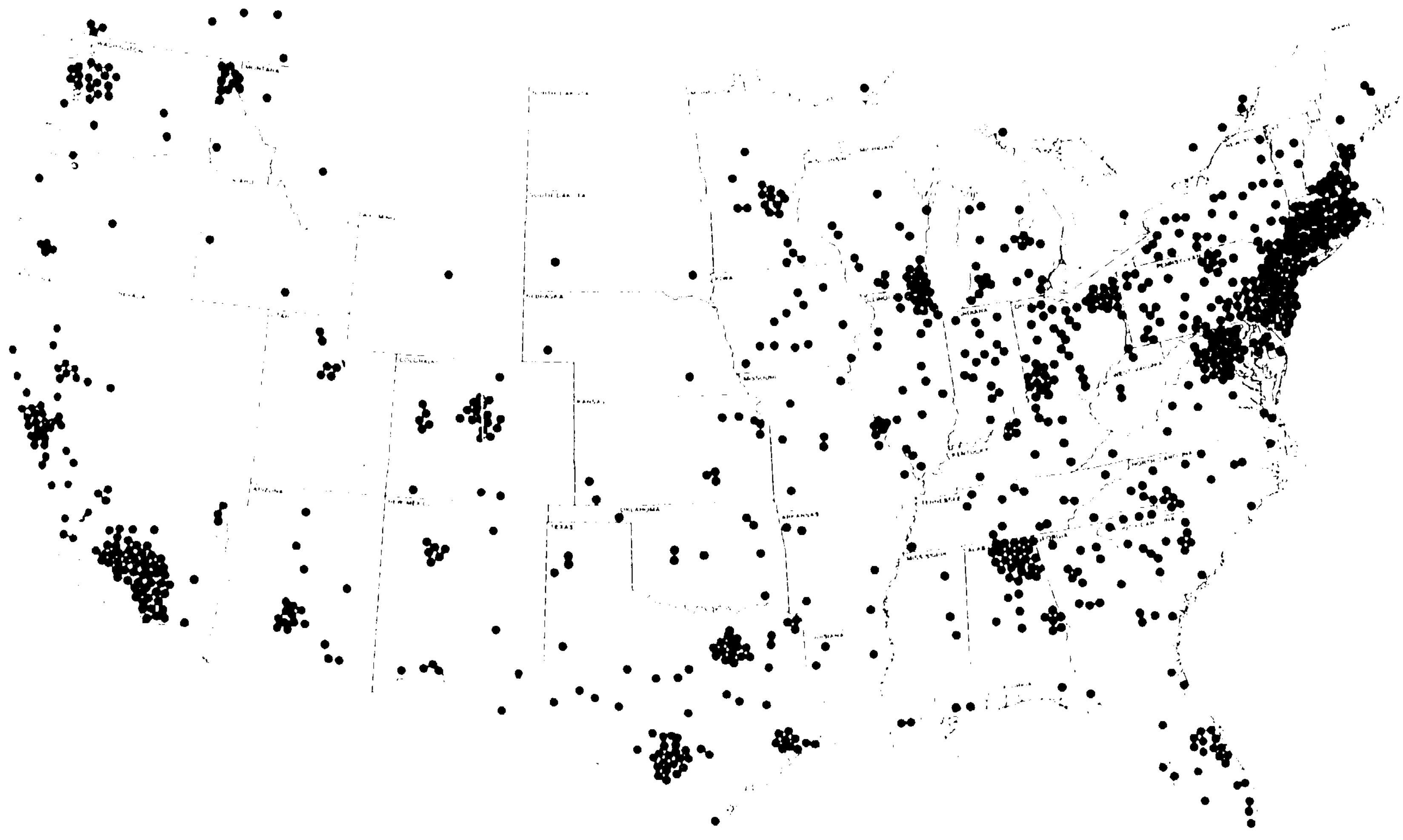
ATLAS 1 - SEPAC - INSPIRE

Interactive NASA Space Physics Ionosphere Research Exp.

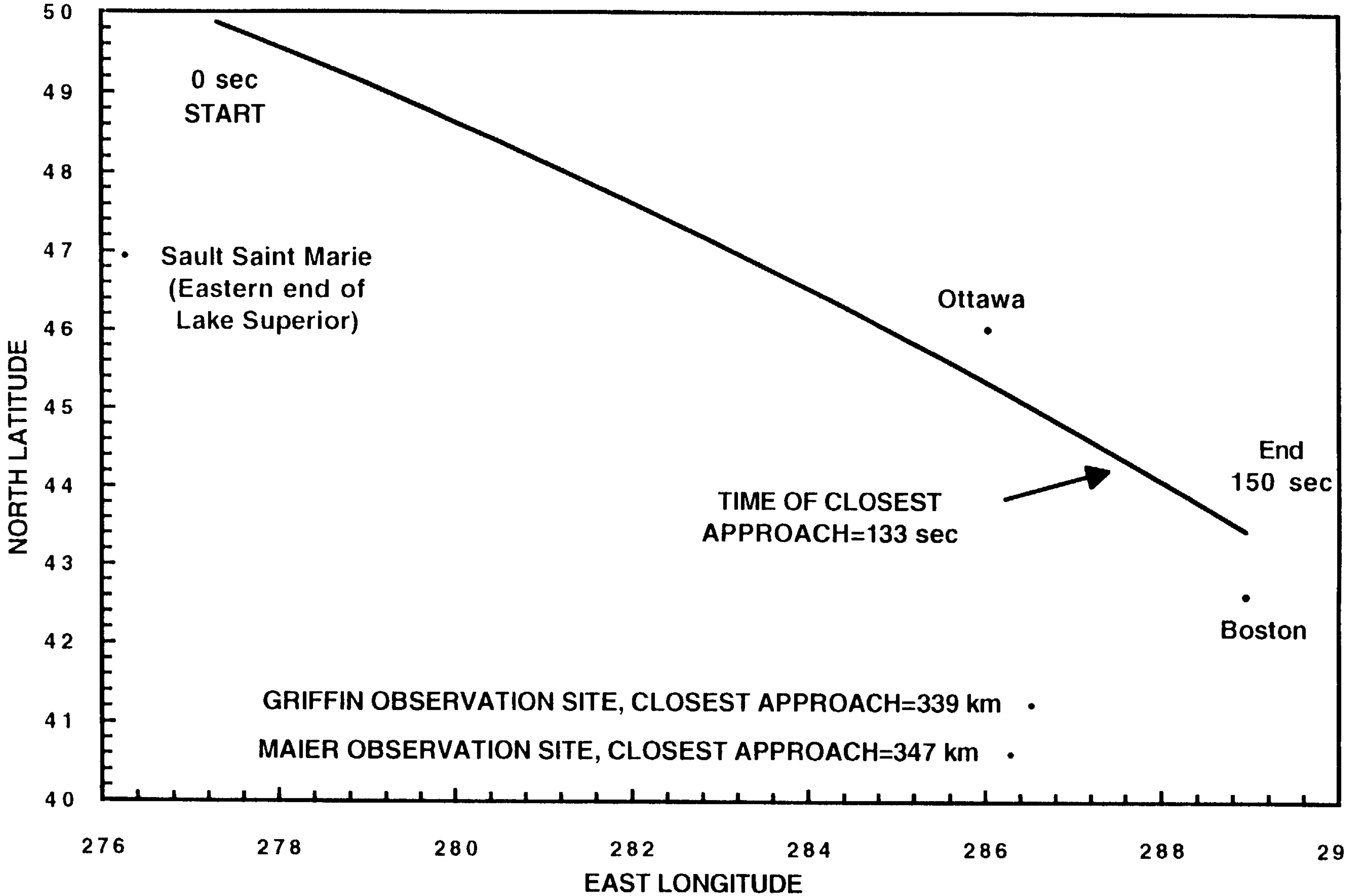
SUMMARY

- Enhancement of SEPAC science
- Educational program to INSPIRE students to excel in science
- SEPAC will emit pulsed electron beam (50 Hz - 7 kHz)
- Students will receive and record waves on cassette recorders
- 1000 classes plus others participating
- Will continue with observations of waves from Tethered Satellite, naturally occurring waves, and radio navigation transmitters

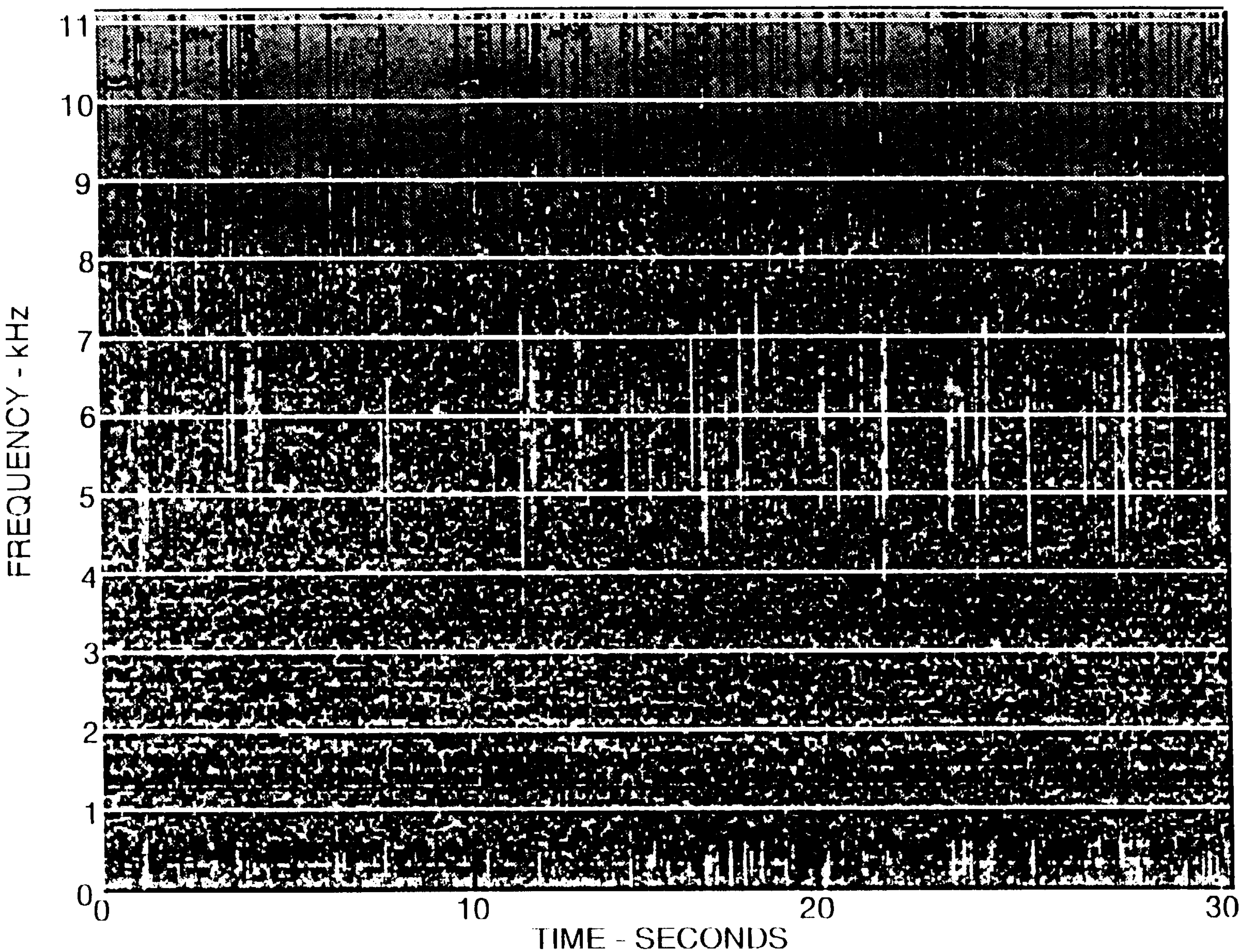
1000 OBSERVING SITES FOR INSPIRE

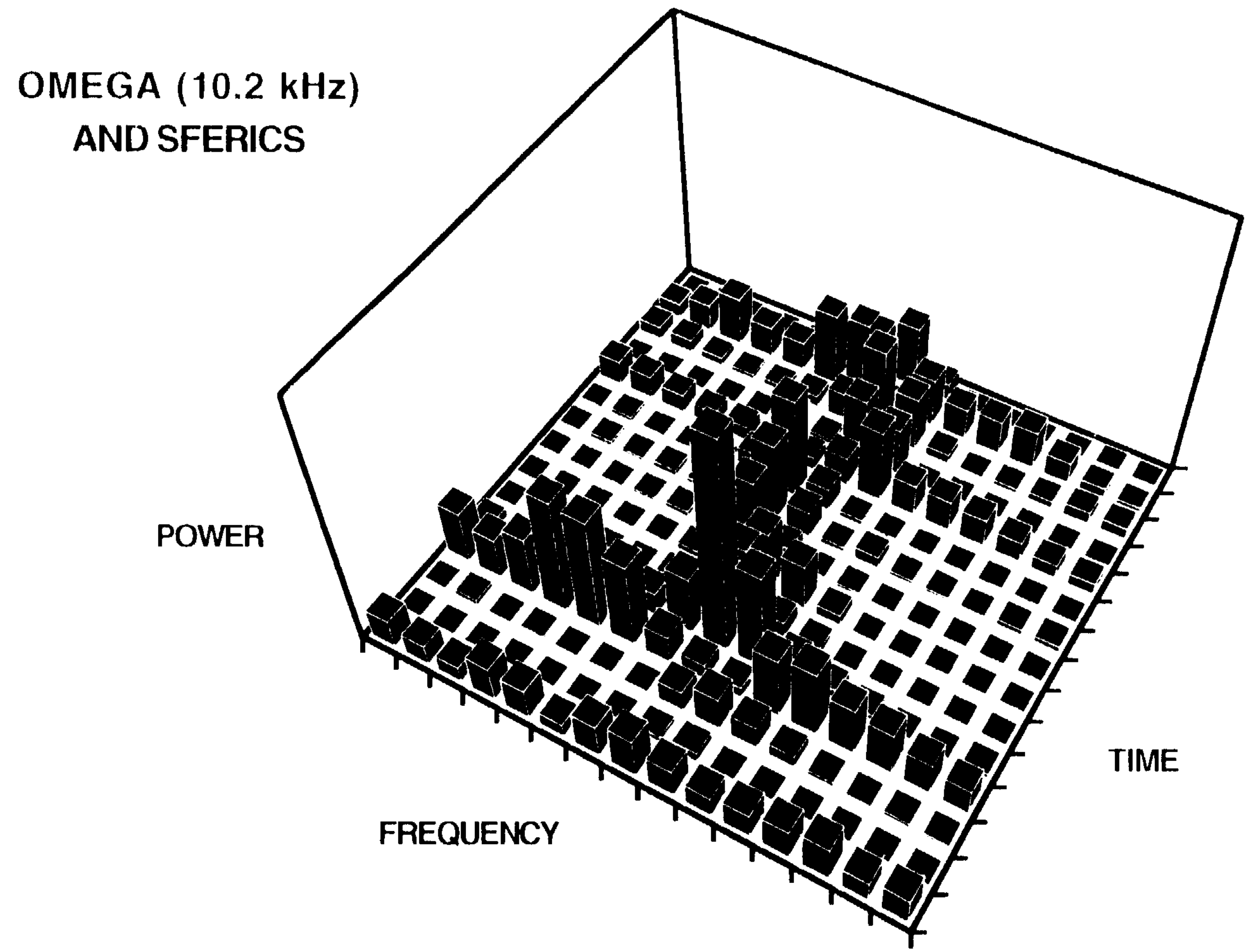


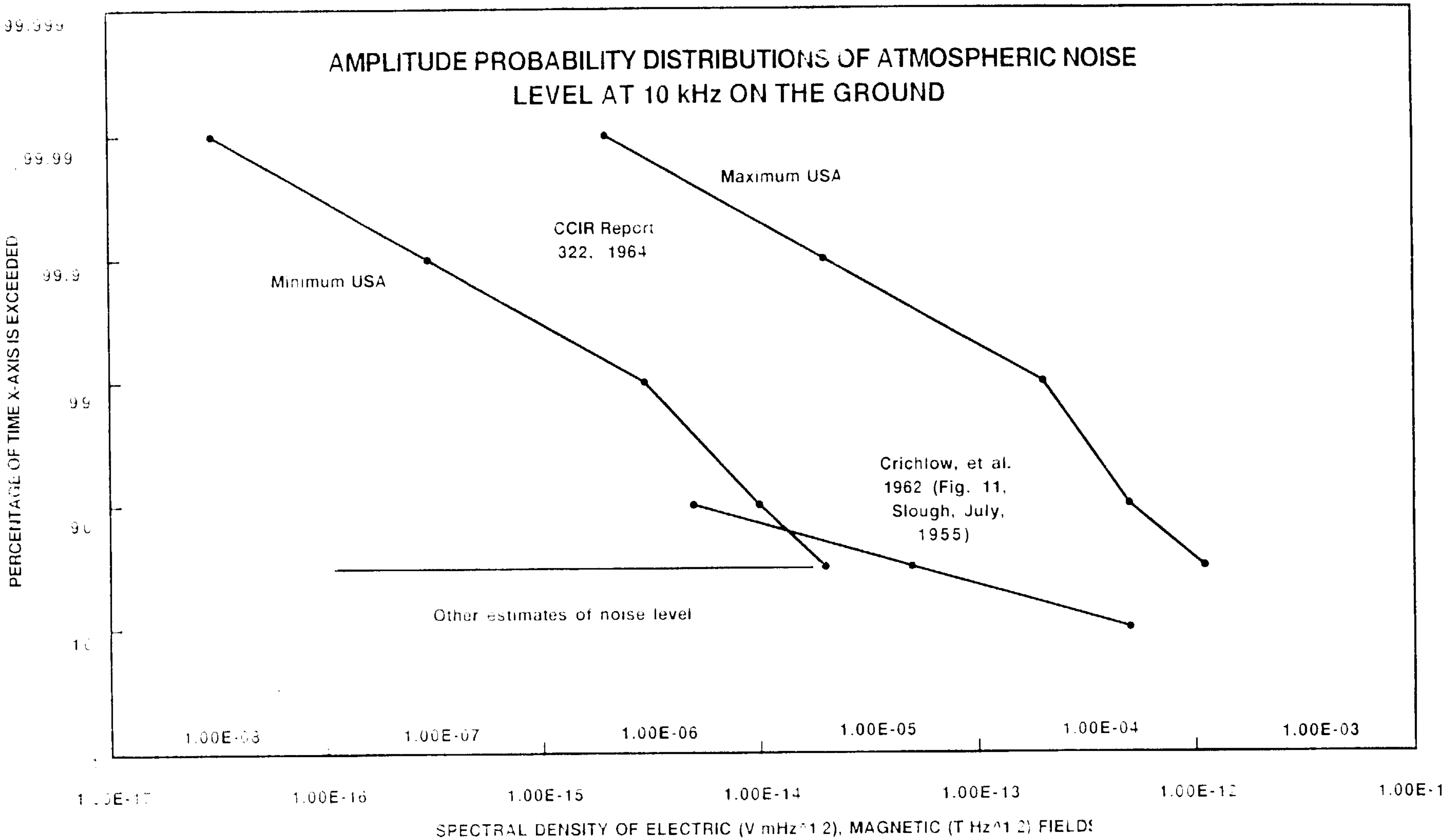
OBSERVATION SITES FOR FO 7-2



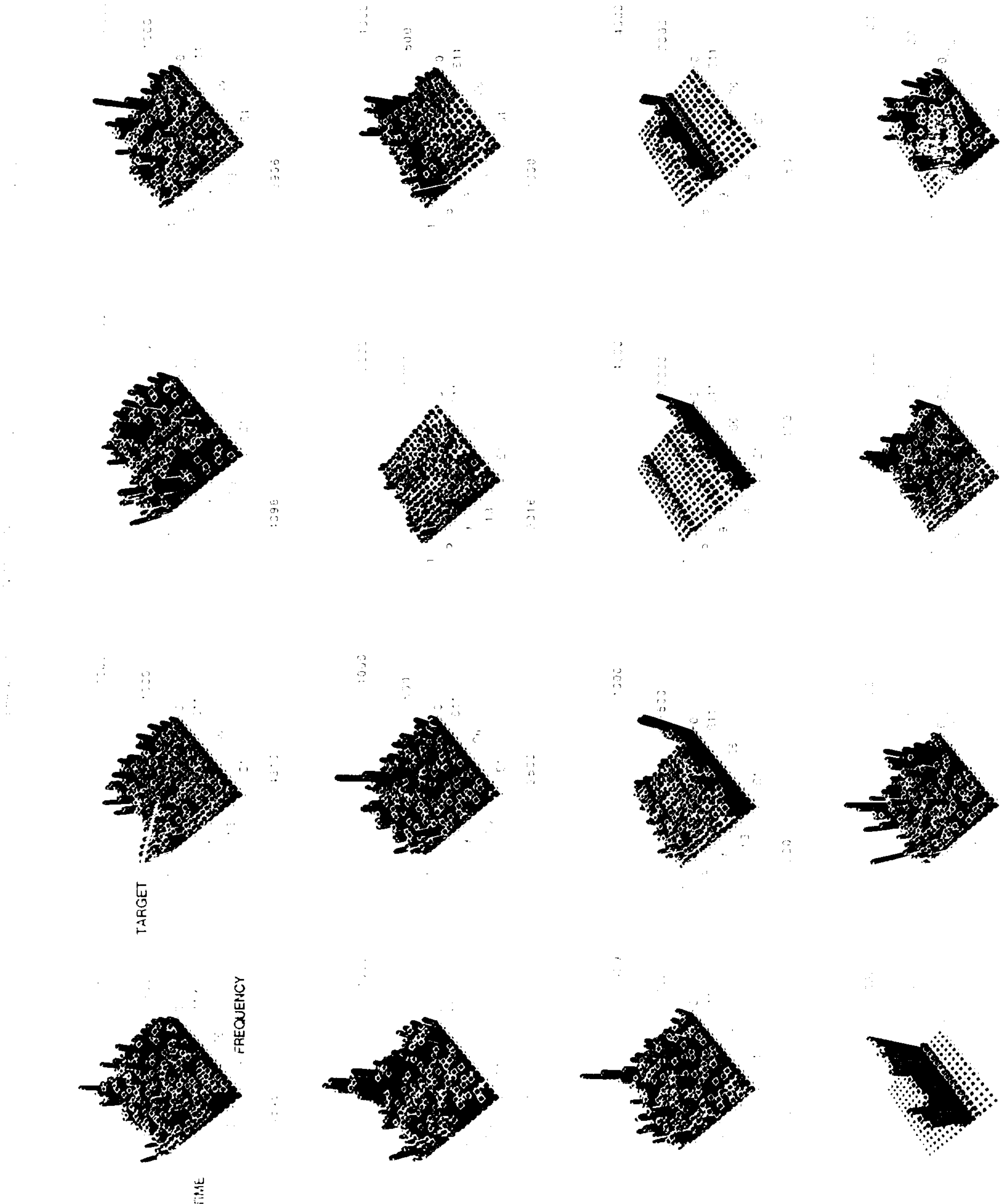
FO 7-2 SECOND HIGH POWER SEQUENCE



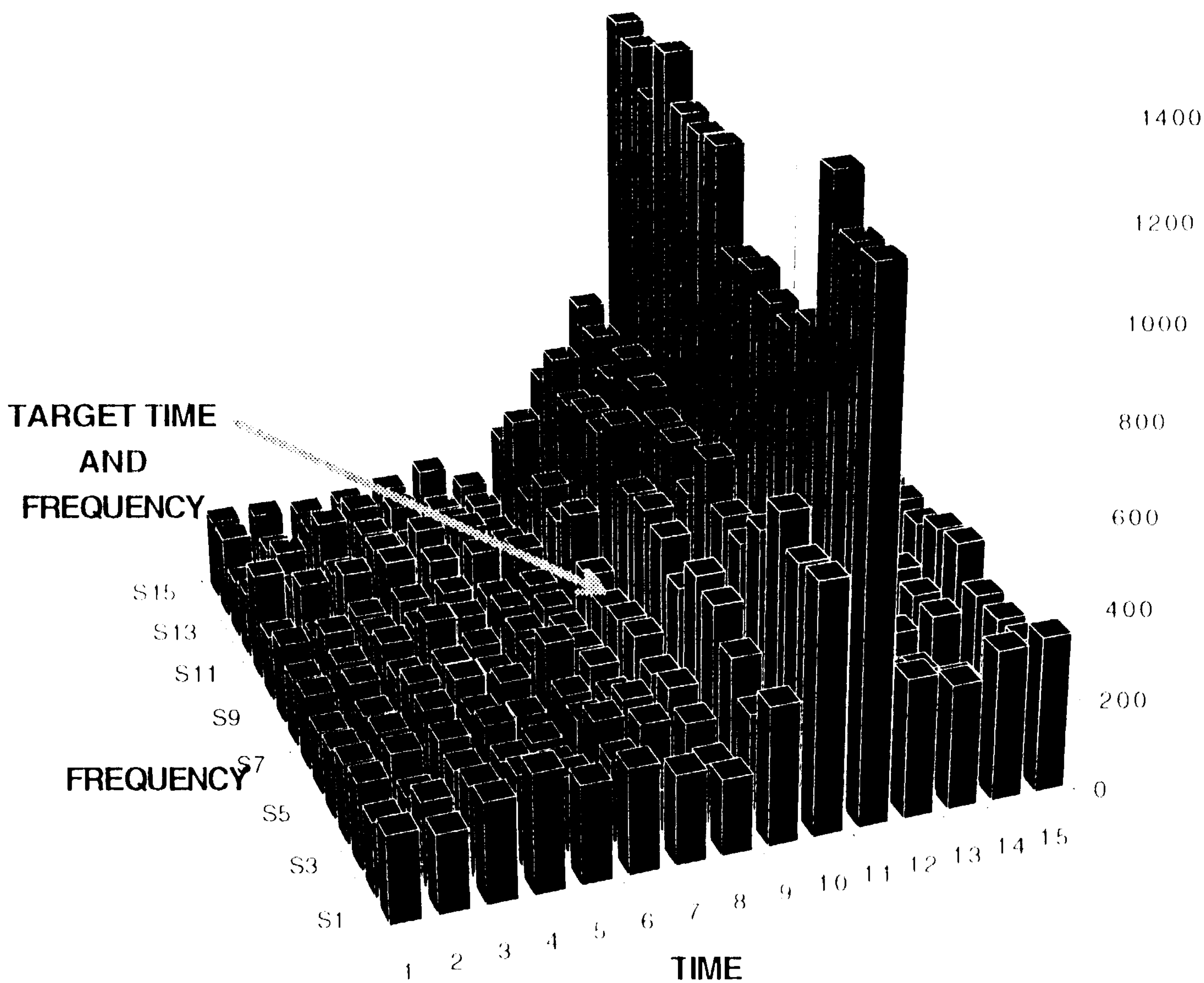

OMEGA (10.2 kHz)
AND SFERICS
POWER
FREQUENCY
TIME



AMPLITUDE PROBABILITY DISTRIBUTIONS OF ATMOSPHERIC NOISE
LEVEL AT 10 kHz ON THE GROUND
Maximum USA
CCIR Report
322, 1964
Minimum USA
Crichlow, et al.
1962 (Fig. 11,
Slough, July,
1955)
Other estimates of noise level
99.99
99.9
99
90
1.00E-07
1.00E-06
1.00E-05
1.00E-04
1.00E-03
1.00E-16
1.00E-15
1.00E-14
1.00E-13
1.00E-11
PERCENTAGE OF TIME X-AXIS IS EXCEEDED
SPECTRAL DENSITY OF ELECTRIC (V mHz^1 2), MAGNETIC (T Hz^1 2) FIELDS

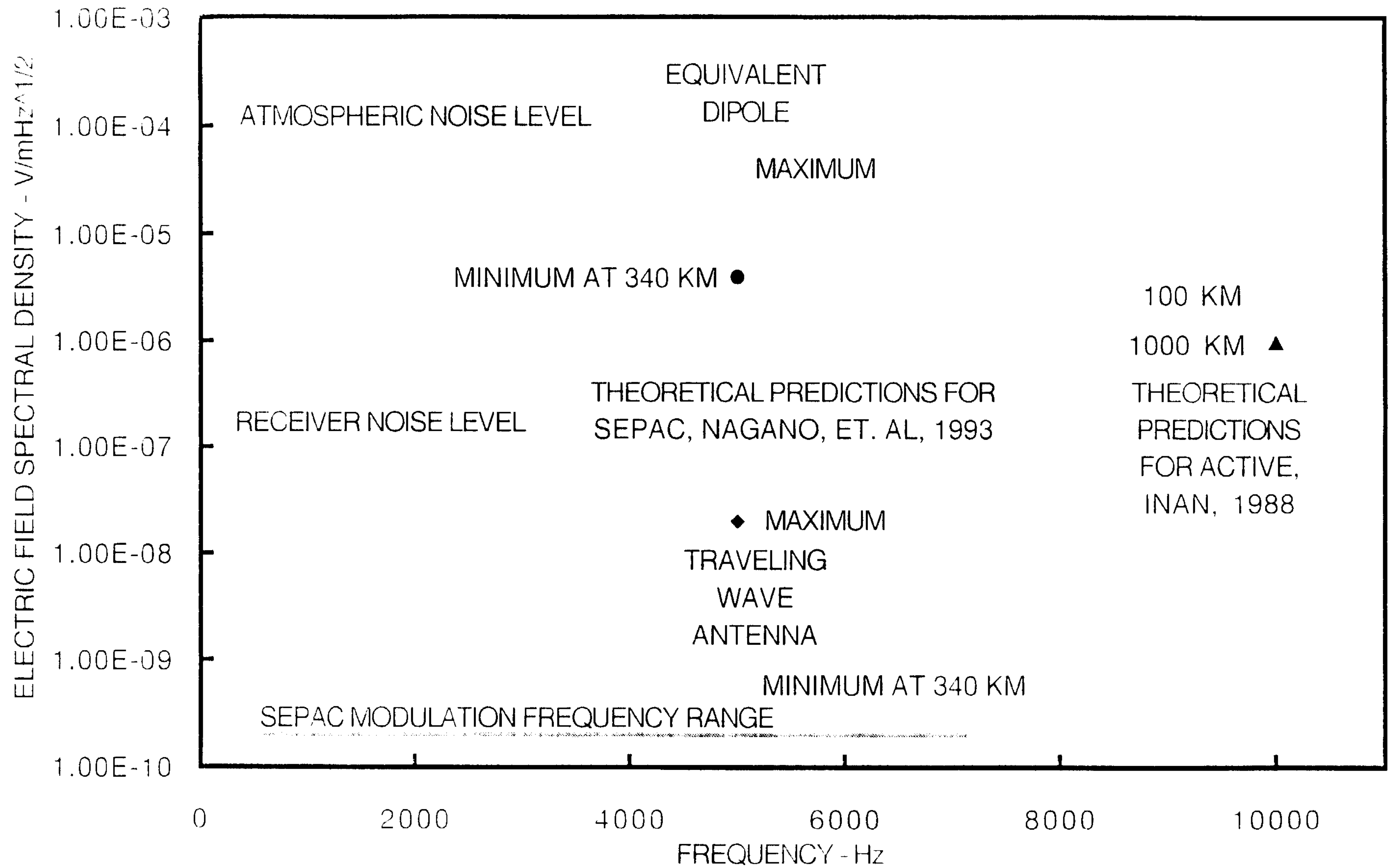

TARGET
FREQUENCY
TIME

AVERAGE OF SEVEN TRANSMISSIONS, ALL FREQUENCIES



C-2.

OBSERVATIONS OF SEPAC VIRTUAL ANTENNA EXPERIMENT



CONCLUSION

Electromagnetic waves from the SEPAC virtual antenna experiment performed on ATLAS 1 over the northeastern United States in March 1992 were not detected by receivers on the ground below the transmitter. The experiment was conducted over the frequency range of 50 Hz to 7 kHz. Over this frequency range, the measured noise level of the receivers was one half to two orders of magnitude below the ambient noise level during the experiment. The noise level above a few kHz was set by the background of worldwide atmospherics propagating in the earth-ionosphere waveguide.

The upper limit to the electric field spectral density of the electromagnetic waves on the ground, from the virtual antenna experiment is 10^{-5} to 10^{-4} Volts/meter•Hertz$^{1/2}$.

Predictions made by Nagano, et. al. 1993, of the expected signal strength on the ground from the virtual antenna experiment are consistent with these results. They concluded that a traveling wave antenna was the best model for the SEPAC virtual antenna. Their full wave calculation predicted a maximum spectral density on the ground of 2×10^{-8} Volts/meter•Hertz$^{1/2}$, with a minimum spectral density of 6×10^{-10} Volts/meter•Hertz$^{1/2}$ at a distance of 340 km. Assuming an equivalent dipole, they calculated 4×10^{-6} to 4×10^{-5} Volts/meter•Hertz$^{1/2}$.

REPORT DOCUMENTATION PAGE

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1. AGENCY USE ONLY *(Leave blank)*

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Huntsville, AL 35812

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11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited; public release authorized.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

INSPIRE (Interactive NASA Space Physics Ionospheric Research Experiment) is a non-profit scientific, educational corporation whose objective is to bring the excitement of observing natural and manmade radio waves in the audio region to high school students. Underlying this objective is the conviction that science and technology are the underpinnings of our modern society, and that only with an understanding of science and technology can people make correct decisions in their lives, public, professional, and private. Stimulating students to learn and understand science and technology is key to them fulfilling their potential in the best interests of our society. INSPIRE also is an innovative, unique opportunity for students to actively gather data that might be used in a basic research project, as is being done with INSPIRE data taken during the recent flight of SEPAC on ATLAS 1. INSPIRE began with a test bed project, ACTIVE/HSGS, which involved 100 high schools, with a centerpiece of making observations of transmissions from the Soviet ACTIVE satellite. The second major project was support to SEPAC in which 1,000 schools participated.

14. SUBJECT TERMS
Active experiments.

15. NUMBER OF PAGES
51

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

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The Report Documentation Page (RDP) is used in announcing and cataloging reports. It is important that this information be consistent with the rest of the report, particularly the cover and title page. Instructions for filling in each block of the form follow. It is important to ***stay within the lines*** to meet ***optical scanning requirements***.

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G	- Grant	TA	- Task
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